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MODELS OF MAINTENANCE RESOURCES INTERACTION: WARTIME SURGE

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The primary objective of this effort was to provide the Air Force with models of the interactive effects of manpower, spares, and support equipment for a current operational system in a wartime surge. Initial tasks established the wartime surge data requirements of an F-15 fighter, the available sources of data, and the critical variables selected for the Logistics Composite Model simulations. The simulated environments relate directly to the base level data, e.g., flying profiles, mission, and resource allocation levels. The majority of the data for this study was obtained from the following sources: (a) Air Force and contractor publications; (b) Maintenance Data Collection (MDC) systems; and (c) Structured interviews with operations and maintenance personnel. Regression models were developed for

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significant Logistics Composite Model (LCOM) variables. The LCOM and the regression models of interaction developed by this research effort can be applied to design and management issues related to readiness assessment.

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SUMMARY

Objectives

The primary objective was to demonstrate a simulation modeling methodology for forecasting weapon system readiness in a wartime surge environment. The secondary objectives were (a) to quantify the interactive effects of manpower, spares, and support equipment for the F-15 operational weapon system in a wartime surge environment and (b) to develop mathematical models of resource interactions.

Background

The concern for military readiness has prompted efforts to forecast the resources for sustained surge operations and maintenance (O&M) of tactical aircraft. Previous research and development (R&D) has demonstrated the use of simulation and modeling techniques to predict resource needs for peacetime operations. However, a surge O&M environment is characterized by conditions which have an impact that cannot be extrapolated from peacetime simulations. For this reason, a need exists to extend simulation and modeling techniques to a wartime surge environment.

Approach

The specific R&D approach progressed through the stages of (a) a definition of a Logistics Composite Model (LCOM) maintenance data base, (b) the development of wartime surge scenario and operation ground rules, (c) the adoption of experimental designs and methods for selecting resource quantities, (d) statistical examination of LCOM output measures, and (e) the derivation of regression models for each output measure as a function of resource quantities.

Specifics

Method. The LCOM was used to simulate 30 days of surge flying activity, assuming an operational wing of 72 F-15 aircraft. Three levels of manpower, four levels of spares, and three levels of support equipment were combined factorially, yielding 36 separate simulations. The interactive effects of the three types of resources, based on the 30-day surge period, were examined for 40 weapon system performance measures. Performance measures were commonly used metrics relative to operations, aircraft, manpower, shop repair, spare supply, and support equipment.

Two sets of regression models for predicting sortie rates were derived for each of the 40 performance measures. The first set of models used only the three types of resources (i.e., manpower, spares, support equipment), as the independent variables, whereas the other set included the surge period (in days) as an additional independent variable.

Findings and Discussion. The major sources of variance in 40 performance measures were attributable to spares and to day of surge activity. The models indicated that as resources were exhausted in the early days of the wartime surge, flying activity deteriorated rapidly. Manpower, support equipment, and interactions among the three principal resources accounted for smaller portions of variance than did either spares or days. The levels of each resource controlled the impact of the variable so output measures of system performance will not be sensitive to resource limitations if the levels are high enough for most demands to be easily satisfied.

The regression models that used only the three types of resources as independent variables did not provide accurate predictions of system performance. The expanded models that included the surge period as an additional variable resulted in reasonably accurate predictions of the 40 performance measures (e.g., percentage of sorties/missions accomplished).

Conclusions/Recommendations

The application of simulation modeling technology for forecasting weapon system readiness in a wartime surge environment was demonstrated successfully. The technology can be used to generate adequate estimates of sorties or missions accomplished under wartime surge conditions.

The regression models developed satisfactorily represented the interactive effects of manpower, spares, and support equipment on sorties and missions accomplished by F-15 units under wartime surge conditions.

It is recommended that this approach be extended to include the effects of variables not examined by this study; for example, (a) the causal relations between the measures of performance and the resource quantities and (b) the impact of chemical warfare environment, variations in mission scheduling, deployment policies, organization structures, and battle damage assessment.

PREFACE

This technical report is one of a series of reports under Contract No. F33615-77-C-0074, Development of Models of Maintenance Resources Interaction. Five of these were published as McDonnell Douglas Corporation reports. Two of them are AFHRL-TR-82-19 and AFHRL-TR-82-20.

The study was directed by Logistics and Human Factors Division, Air Force Human Resources Laboratory, Wright-Patterson Air Force Base, Ohio. The Air Force Human Resources Laboratory Project Scientist was Dr. Ross L. Morgan.

This research was documented under Work Unit 1710-00-23, "Development of Models of Maintenance Resources Interaction." Frank A. Maher was the Work Unit Scientist and Air Force Contract Monitor. The McDonnell Douglas Corporation Program Manager was Carl F. Asiala.

The authors wish to extend their appreciation to the many people within the government and private industry who contributed their time and expertise throughout the course of this research.

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I. INTRODUCTION

PROBLEM

A growing concern in the Air Force is the readiness to engage in sudden or protracted military conflicts. This concern has prompted efforts to forecast the manpower, spare parts, and support equipment needed to sustain operations and maintenance (O&M) of several tactical aircraft. However, forecasting resource levels is not a simple task. The O&M environment changes as a function of factors such as flying activity, environmental conditions, weapon systems in the inventory, weapon system complexity, and changes in maintenance concepts. Thus, to estimate weapon system readiness, methods are needed that can accommodate various configurations of the O&M environment and changes in scenario and support concepts.

Previous studies reported by the authors (References 1-4) established a process for estimating resource requirements of a 72-aircraft wing of F-15s during sustained peacetime operations. Several variations in logistics support, utilization scenario, and maintenance concept were introduced, and results were examined statistically to determine the quantitative impact of these variations on performance. Furthermore, mathematical models were developed as predictive devices which generalized the quantitative relationships between environmental variations and performance. Simulation modeling, augmented with mathematical modeling of performance measures, was shown to yield a powerful analytic tool for estimating peacetime resource needs.

The Air Force Human Resources Laboratory (AFHRL) has addressed the peacetime O&M environment. However, a methodology is needed to show the marginal change in sortie generation of a unit of tactical aircraft in the combat surge environment as a function of differing levels of manpower, spares, and support equipment available to the unit when committed to combat. These unit resource levels must be translated into funding levels for the Force Structure in the budget and POM (Program Operations Memorandum). This methodology would be used to assist in balancing resources across weapons systems and to satisfy the Congressional mandate that support resource funding be explicitly related to levels of readiness.

In this context, readiness is defined as the number of sorties that can be generated during the initial surge phase of air operations.

The purpose of the present study was to extend the peacetime simulation and mathematical modeling technique to an initial wartime surge environment.

This study examined the influence of variations in manpower, spares, and support equipment quantities on F-15 operations and maintenance assuming the heavy flying demands typical of a surge scenario. Dynamic interactions among resource levels were studied for each of 30

successive days, and results were used to develop predictive models that relate daily changes in more than 40 performance measures to variations in resources.

Specific study objectives were: (a) to quantify the interactive effects of manpower, spares, and support equipment for F-15 operational weapon system in an initial wartime surge environment, and (b) to develop mathematical models of resource interactions.

II. APPROACH

Several techniques are available for predicting system performance as a function of resource quantities, and each has advantages and disadvantages with respect to sophistication, fidelity with actual operations, flexibility, cost, and turnaround time. Paper-and-pencil surveys can provide results rapidly and inexpensively, but generally yield little insight into complex interactions among the weapon system and its resources. At the opposite end of the continuum, actual flight testing under hypothetical operating conditions can provide a wealth of detailed information about complex interactions. However, these exercises are extremely expensive, require prolonged periods to collect useful data, and may be very restrictive in terms of objectives that they satisfy. Hence, a technique more sophisticated than paper-and-pencil surveys and less expensive and time-consuming than flight testing is needed to give designers and managers early quantitative data on projected system performance.

Computer simulation modeling represents a powerful, timely, and relatively inexpensive method for generating quantitative relationships between performance measures and resource quantities. Using a simulation model, an investigator can examine virtually any real or hypothetical configuration of an O&M environment of any weapon system. Among the available computer models to provision for spares and manpower (References 5 to 12), the Maintenance Manpower Model developed by the AFHRL has been used extensively. The Air Force maintains highly detailed data bases of the characteristics and support environments of several tactical aircraft in accordance with AFR 25-8. Aircraft systems currently covered include the F-4E, RF-4C, F-4G, F-15, F-16, F-111A, EF-111A, A-10, A-7D, and C-5A.

The Maintenance Manpower Model incorporates the Logistics Composite Model (LCOM) (References 13 to 16) and provides a technology for forecasting the maintenance manpower requirements for a weapon system (Reference 7). Using Air Force base-level data related to aircraft maintenance and support functions, LCOM simulates an operational aircraft squadron or wing at a specified level of flying activity over time (References 8 to 12). Outputs from these exercises include detailed information about simulated operational activity on a day-by-day basis (e.g., sorties requested and accomplished), aircraft maintenance (e.g., post-sortie turnaround time), personnel use, shop repair, supply and support equipment use. By varying levels of manpower, spares, and support equipment assumed to be available at the start of simulation, investigators have been able to examine the interrelationships among these resources as they influence weapon system performance. Simulation results can be used to optimize resource quantities and tradeoffs between resources, and in this way contribute to readiness.

The specific research program progressed through the following stages:

1. Define maintenance data base

2. Develop surge scenario and operation ground rules

3. Adopt experimental design and methods for selecting resource quantities

4. Statistically examine LCOM output measures

5. Derive regression models for each output measure as a function of resource quantities

DEFINITION OF THE DATA BASE

Simulations were performed with an F-15 data base which is described in detail in Reference 1. This data base had been configured following review of Air Force and contractor publications devoted to F-15 maintenance requirements, examination of the maintenance data collection system (References 17 and 18), and consultation with Continental United States (CONUS) and European base maintenance personnel. Maintenance tasks and aircraft components were described at the standard five-digit work-unit-code level adopted by the Air Force (Reference 19), and configured appropriately for LCOM use (References 13 to 16). Operations with the F-15 concerning deployment, flying rates, weapons use, alert requirements, flight sizes, mission types, and launch time separations were guided by Air Force policies. Similarly, maintenance concepts that defined work centers, manning standards, frequency of scheduled maintenance, task priorities, base and depot repair time, flightline activities, and cannibalization of downed aircraft for spare parts, all were chosen in light of Air Force practices and data (see Appendix A). Expected failure rates and repair times were provided to the data base for over 400 line replaceable units (LRUs) that were considered to be "maintenance significant," i.e., at least one maintenance action was expected in approximately 5000 sorties. Military personnel were designated by their Air Force Specialty Code (AFSC), and maintenance activities of 38 AFSC types assigned to 10 different work centers were monitored. Further detail on data base characteristics can be found in Reference 1.

SURGE SCENARIO AND OPERATION GROUND RULES

Reference (20) provided some information on combat sortie generation. Each simulation performed in the present study assumed the same F-15 utilization program and several additional operating restrictions. The utilization program spanned 30 days of O&M activity, and prior to the first day, a wing of 72 aircraft and supporting manpower, spares supply, and equipment were assumed fully operational.

Surge flying activity described a positively skewed histogram of missions and sorties requested as a function of days. That is, the greatest level of flying activity was requested on the first surge day,

and then decreased across days 2 and 3 to a level which remained high but constant from days 4 through 30. An effort was made to optimize mission scheduling within each day so that peak demands for aircraft would occur when most aircraft were expected to be available, i.e., following the completion of sorties or maintenance and service. Across all 30 days, the flying program yielded an aircraft utilization rate (UR) of 135 sorties per aircraft per month, although sortie rates achieved varied as a function of resources. Sortie durations were held constant for different mission types. In-sortie activity was not simulated.

Each day allowed for 12-daylight and 2-nighttime hours of flying activity for a total of 14 hours per day. Missions were scheduled for all 7 days per week. Maintenance manpower was made available on all 30 days according to two 12-hour shifts. Manning levels per shift corresponded to Air Force policies and to the quantities assigned via the experimental design.

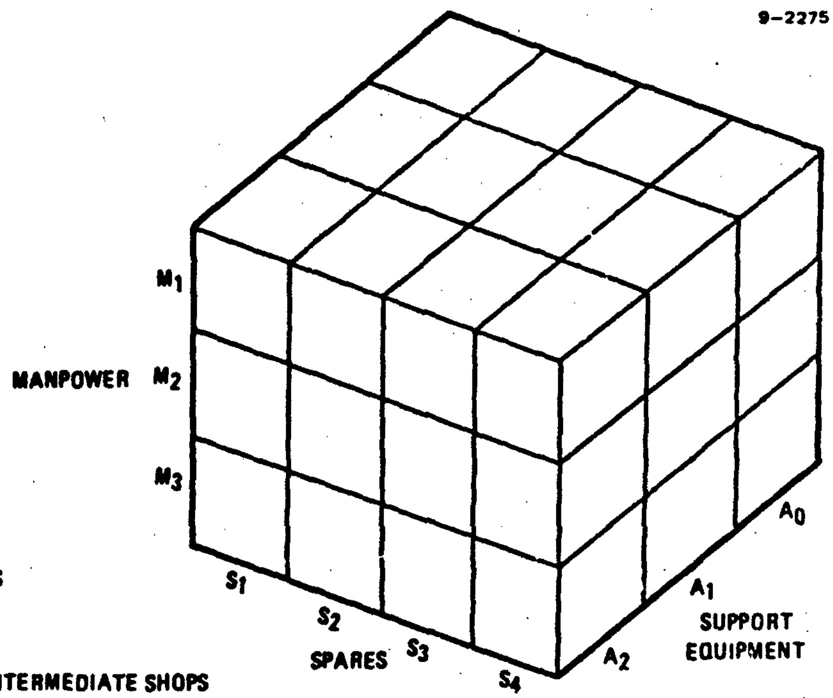
Cannibalization of parts from non-operational aircraft was permitted in all simulations. Generally, Air Force policy calls for avoiding cannibalization for a variety of reasons, but under surge operations exceptions can be made. It was assumed cannibalizations would occur only when spare parts were not available from supply and the aircraft in maintenance could not be repaired before the next scheduled sortie.

Resupply of spares repaired at the depot was not allowed. In operational settings, some percentage of failed aircraft components are routed to the depot to be repaired; the remainder are repaired on base. In the present scenario, repair pipeline time from the depot was set at a value greater than 30 days, which meant that there was a continuous drain on potential supplies as a function of failures.

EXPERIMENTAL DESIGN AND METHODS FOR SELECTING RESOURCE QUANTITIES

The purpose of this study was to examine the effects of a wide range of resource levels on system performance across the 30-day surge. Therefore, simulation runs differed with respect to the quantities of men, spare parts, and support equipment available beginning on the first day of surge activity. Three levels of manpower, four levels of spares, and three levels of support equipment were combined in a factorial arrangement yielding 36 separate "cells," i.e., each level of a variable appeared in combination with each level of all remaining variables. Figure 1 illustrates the experimental design for this study and lists the actual quantities of men, spares, and equipment in terms of AFSCs, LRUs, and Avionics Intermediate Shops (AISs), respectively. Within each cell there were 30 successive days and, therefore, 30 observations per LCOM performance measure. Thus, across all simulation runs, 3x4x3x30 = 1080 observations per measure were obtained as a function of manpower, spares, support equipment, and days.

The resource quantities chosen reflected a concern with avoiding weapon system performance extremes for which the effects of the resource



S_4 = 1431 LRU
S_3 = 1188 LRU
S_2 = 728 LRU
S_1 = 463 LRU
M_3 = 1572 PERSONS
M_2 = 972 PERSONS
M_1 = 781 PERSONS
A_2 = 2 AVIONICS INTERMEDIATE SHOPS
A_1 = 1 AVIONICS INTERMEDIATE SHOP
A_0 = ZERO AVIONICS INTERMEDIATE SHOP

FIGURE 1 WARTIME SURGE SIMULATION PLAN
Manpower X Spares X Support Equipment With Cannibalization

variations would be undetectable. If, for instance, nearly all of the sorties requested are accomplished across simulations that use different resource quantities, then a "ceiling" effect prevents any inferences regarding the magnitudes of experimental manipulations. Therefore, different resource quantities were chosen, based on preliminary simulation results, to ensure large variations in system performance.

First, three simulations were conducted with unlimited manpower, spares, and support equipment to determine the best performance possible under an aircraft utilization rate (UR) of 135 flying hours per aircraft per month. The three runs sampled the inherent random processes in the model and, therefore, produced a "band" of performance. Figure 2 illustrates this performance band in terms of percent of requested sorties accomplished per day. As can be seen, even with unconstrained resources the frag rate required to meet a UR of 135 simply was too high with the restrictions that the initial ground rules imposed (72 aircraft and a 14-hour flying window per day). Percent sorties accomplished increased from about 76% to 92% across Days 1 to 4 and then remained relatively constant near 92% through Day 30. The three unconstrained runs yielded a variation in percent sorties accomplished of approximately ±3% around the mean on any given day.

Once the band of percent sorties accomplished was established, resources were constrained to lower quantities to keep the sorties accomplished rate within the band. These resource levels represented the baseline values. As can be seen in Figure 2, baseline resource conditions consisted of 1431 LRUs, 1572 persons, and two Avionics Intermediate Shops (AISs), each shop comprised of six avionics test stations. Additional levels of each resource then were selected to satisfy the experimental design.

Manpower levels equaled 781, 972, or 1572 persons distributed across 38 AFSC types and two work shifts. These values were selected based on earlier work (Reference 3) and satisfied manning requirements for UR=10, 20, and 30 peacetime flying schedules, respectively. Actual frequencies of men per AFSC appear in Appendix B.

Totals of 463, 728, 1188, or 1431 spare parts distributed across 411 different LRUs constituted the four levels of spares. The lower two spares quantities, 463 and 728, were selected based on prior research (Reference 3) which showed these quantities to be satisfactory for UR=10 and 30 schedules, respectively. The larger quantities, 1188 and 1431, were determined by treating requests for LRUs as a Poisson distributed process given anticipated failure rates and 30 days of flying. The two values were computed to ensure that requested spares would be available with a probability of .95 for a UR=90 and a UR=135, 30-day schedule, respectively. Appendix C presents actual spares quantities per LRU, and Appendix D discusses the procedures for using the Poisson distribution.

Support equipment associated with the AIS test stations was constrained to either 0, 1, or 2 of each drawer per test station. The AISs

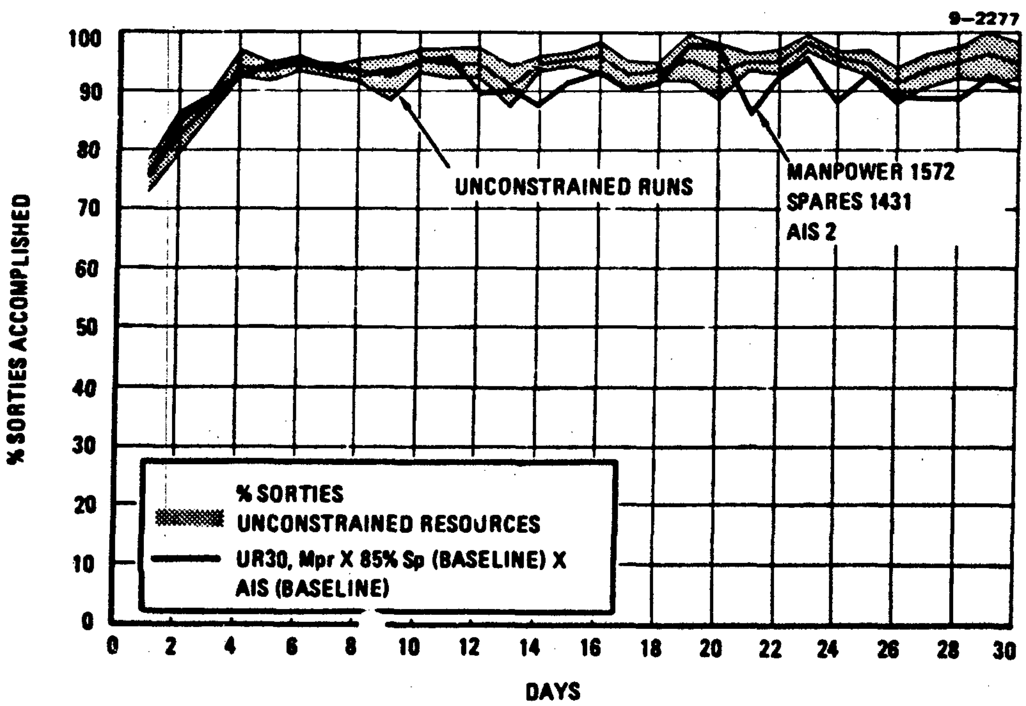


FIGURE 2 SORTIE EFFECTIVENESS FOR UNCONSTRAINED AND BASELINE RUNS

are used to repair failed LRUs. Constraining the availability of the AIS test stations was expected to delay or eliminate spares resupply and impair system performance.

In addition to the AIS, the following support equipment and facilities were simulated at constant levels over all runs:

Equipment		Quantity
AM32A-60A:	Gas turbine generator set...........	unconstrained
TTU228/E:	Hydraulic test stand................	unconstrained
NF2:	Self-contained light stand..........	unconstrained
68D:	20-MM loader........................	1
189F168:	20-MM loader........................	1
MHU83A/E:	Munitions handling lift truck.......	3
MJ-1A:	Aerial stores lift truck............	2
HOTPIT:	Quick turnaround area...............	6
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LCOM OUTPUT MEASURES EXAMINED

Forty LCOM dependent measures, grouped into six performance categories, were extracted from each daily summary of flying activity for all 36 simulations. A list of the measures appears in Table 1. As a result of the design adopted, there were 1080 observations for each of these measures.

Within a given category, values for each dependent measure were collected on each subcategory, but statistical analyses were performed only on values totaled across all subcategories. For instance, Percent Sorties Accomplished was a measure available for each of the mission types in the Operations category. However, analyses were conducted only on Percent Sorties Accomplished accumulated across all mission types. Similarly, measures in the Manpower category were accumulated over all AFSCs; in the Shop Repair and Supply categories across all LRUs; and in the Support Equipment category across all AIS drawers and remaining equipment.

STATISTICAL ANALYSES

The effects of changes in resource quantities on the 40 measures were examined with two sets of stepwise regression analyses (Reference 21). For each measure, a regression model was derived using single degree-of-freedom components of the main effects and interactions between Manpower, Spares, and Support Equipment. Variation attributable to Days was treated as error. A second model was generated for each measure which included selected components of the Days main effect and their interactions with all the remaining factors from the first regression analysis. Table 2 summarizes the 26 sources of variance and their degrees of freedom tested in the first analysis. The second analysis tested 80 sources of variance which resulted when linear and quadratic

TABLE 1 LIST OF LCOM OUTPUT VARIABLES EXAMINED

CATEGORY	DEPENDENT MEASURES NO.	TITLE
OPERATIONS	3	Percent accomplished - Mission
	8	Percent accomplished - Sorties
AIRCRAFT	15	Percent on sorties (including Alert)
	16	Percent in unscheduled maintenance
	17	Percent in scheduled maintenance
	18	Percent in NORS
	19	Percent in mission wait status
	20	Percent in service plus waiting
	21	Percent in operationally ready
	22	Average aircraft post-sortie time (hours)
	23	Average number of sorties per aircraft per day
	24	Flying hours
	T8	Average aircraft pre-sortie time (hours)
MANPOWER	28	Percent utilization
	29	Manhours used (X100)
	30	Percent unscheduled maintenance
	31	Percent scheduled maintenance
	33	Number of men desired
	34	Percent men available (Prime)
	38	Percent demands not satisfied
	40	Simulated maintenance manhours per flying hour
SHOP REPAIR	44	Number of reparable generations
	45	Percent base repair
	46	Percent depot repair
	47	Average base repair cycle
	48	Percent active repair
	49	Percent white space
SPARES SUPPLY	55	Percent fill rate
	56	Number of backorder days
	57	Number of units demanded
	58	Percent units off-the-shelf
	61	Percent demands not satisfied
	62	Number of cannibalizations
	63	Number of items on backorder
SUPPORT EQUIPMENT	71	Equipment percent used - unscheduled maintenance
	72	Equipment percent used - scheduled maintenance
	73	Equipment percent unused
	74	Number of backorder days
	75	Number of units demanded
	79	Equipment percent demands not satisfied
TOTAL	40	

Days components were entered as main factors and in interactions with the 26 sources from Table 2.

In stepwise regression, the form a prediction model eventually assumes is governed by several assumptions. In the present analyses, the one factor selected from the group of factors at each step always had the largest semi-partial correlation with the dependent variable and, therefore, made the largest contribution to total variance accounted, R^2. Factors continued to be admitted to the model only if the F-statistics associated with their variance contribution exceeded the .001 probability level. Furthermore, a factor remained in the model only if its contribution after other factors were entered exceeded a value significant at the 0.05 level. These criteria made both entry of a factor into the model and exit after entry relatively difficult. It should be clear from these remarks and Table 2 that the two prediction models generated for each measure represented two of virtually thousands of potential models. In regression analysis, any factor associated with a degree of freedom can be treated as a testable factor or as error. Furthermore, the order of factor entry as well as statistical criteria used to test each factor are user-defined.

TABLE 2 MAIN EFFECTS, INTERACTIONS, AND ASSOCIATED DEGREES OF FREEDOM FOR VARIATIONS OF MANPOWER, SPARES, AND SUPPORT EQUIPMENT: REGRESSION MODELS WITHOUT DAYS

	SOURCE OF VARIANCE	df	
	Total	1079	
	Manpower	2	
1.a	linear (M)		1
2.	quadratic (M^2)		1
	Spares	3	
3.	linear (S)		1
4.	quadratic (S^2)		1
	cubic[b] (S^3)		1
	Support Equipment	2	
5.	linear (SE)		1
6.	quadratic (SE^2)		1
	Manpower x Spares	6	
7.	$M \times S$		1
8.	$M \times S^2$		1
	$M \times S^3$[b]		1
	$M^2 \times S$		1
	$M^2 \times S^2$		1
	$M^2 \times S^3$[b]		1
	Manpower x Equipment	4	
11.	$M \times SE$		1
12.	$M \times SE^2$		1
13.	$M^2 \times SE$		1
14.	$M^2 \times SE^2$		1
	Spares x Equipment	6	
15.	$S \times SE$		1
16.	$S \times SE^2$		1
17.	$S^2 \times SE$		1
18.	$S^2 \times SE^2$		1
	$S^3 \times SE$[b]		1
	$S^3 \times SE^2$[b]		1
	Manpower x Spare x Equipment	12	
19.	$M \times S \times SE$		1
20	$M \times S \times SE^2$		1
21.	$M \times S^2 \times SE$		1
22	$M \times S^2 \times SE^2$		1
	$M \times S^3 \times SE$[b]		1
	$M \times S^3 \times SE^2$[b]		1
23.	$M^2 \times S \times SE$		1
24.	$M^2 \times S \times SE^2$		1
25.	$M^2 \times S^2 \times SE$		1
26.	$M^2 \times S^2 \times SE^2$		1
	$M^2 \times S^3 \times SE$[b]		1
	$M^2 \times S^3 \times SE^2$[b]		1
	Residual	1044	

III. RESULTS

Two classes of findings are important to the purpose of the present study. First, the concentration was on the empirical relationships between resource levels and observed changes in F-15 performance as reflected in the 40 LCOM measures. Second, the regression models derived from these empirical relationships are discussed and their predictive power evaluated. Examples of the appropriate use of the regression models are presented.

EXPERIMENTAL FINDINGS

The range of resource quantities tested had a dramatic impact on several performance measures examined in all categories. The first consideration is the impact of resource levels on an Operations measure since other measures are directly influenced by activity at this superordinate level. Figure 3 illustrates changes in Percent Sorties Accomplished as a function of all resource levels. Within each panel, Percent Sorties Accomplished is plotted as a function of the four spares levels (x-axis), and the three manpower levels (graphs lines). Each AIS condition is plotted in a separate panel. Each data point in Figure 3 represents the average sortie percent for the 30-day surge. Changes in sortie percent over days are presented later in this section.

Figure 3 shows that as resource quantities were increased, sortie percent increased, not a surprising result. However, some resources clearly had more impact on this measure than others. First, spares levels made the major contribution to sortie percent. Note the rapid increases in sortie percent within each of the three panels. Averaged over manpower and support equipment, sortie percents were 36%, 50%, 70% and 71% for spares levels of 465, 735, 1188, and 1431 LRUs, respectively. It is of interest to note that further increases in LRUs beyond 1188 did not influence sortie rate substantially. This result indicates that restrictions imposed by other resources, the heavy flying demands, and the limited number of aircraft and daily flying window, nullified the advantages of the largest spares supply.

Second, the more support equipment that was available the greater the sortie rate, but the magnitudes of the increases were not as large as when spares were changed. Averaged over manpower and spares, the 0, 1, and 2 AIS conditions produced 50%, 39%, and 61% sorties accomplished. Finally, manpower changes effected the smallest average gains in sortie rates; average percentages for 781, 972, and 1572 personnel were 53%, 56%, and 61%. The small separations between graphs in each panel of Figure 3 indicate manpower had a negligible effect on sortie percent. At first glance, the 8% performance gain achieved with a doubling of manpower from 781 to 1572 AFSCs may appear surprisingly small. However, as will be seen in later discussions of Personnel category measures, even the lowest manning levels produced relatively few unsatisfied demands for personnel.

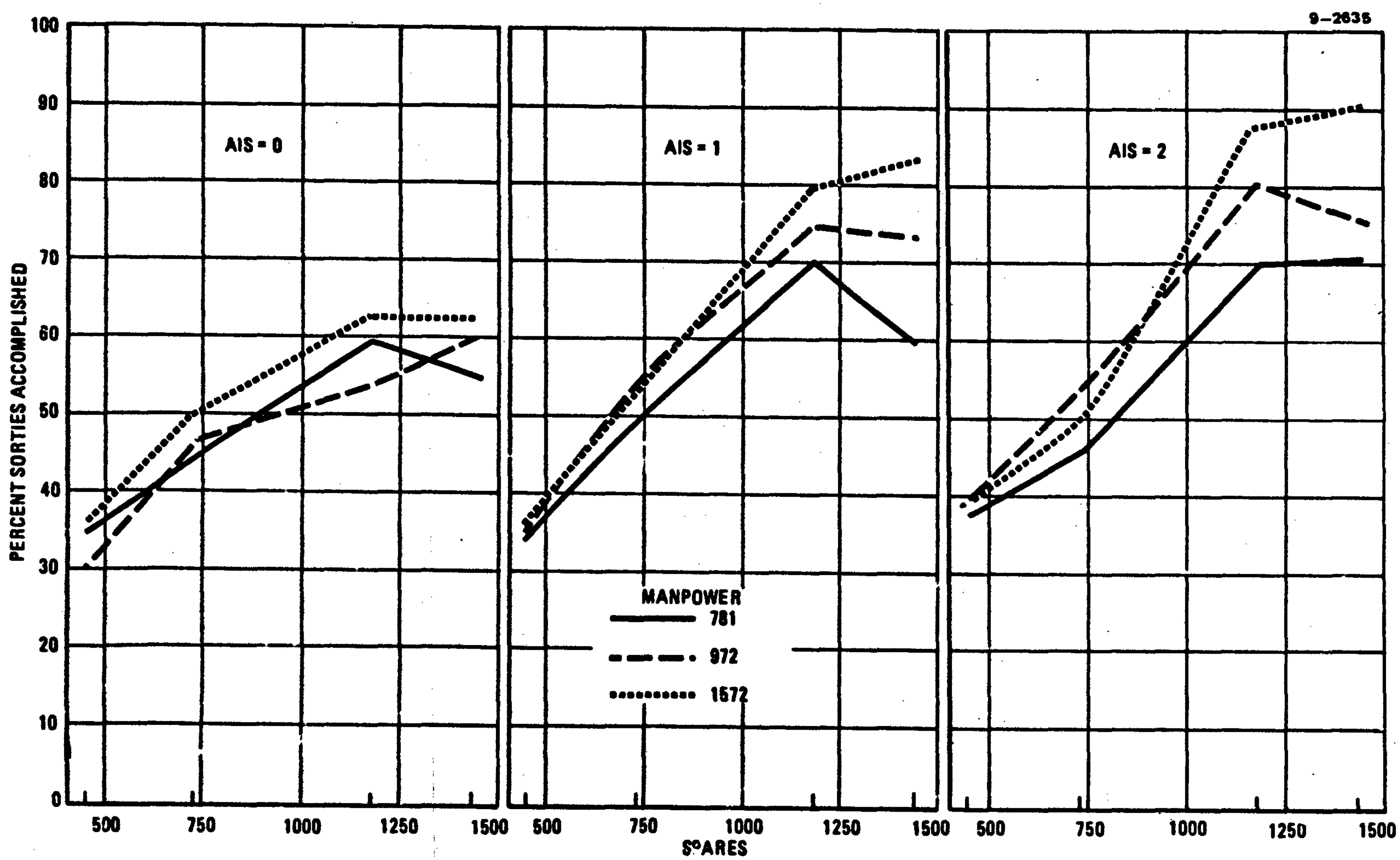

FIGURE 3 PERCENT SORTIES ACCOMPLISHED AVERAGED OVER DAYS FOR ALL LEVELS OF SPARES, MANPOWER, AND SUPPORT EQUIPMENT

The main effects of each resource type were of interest; however, the data in Figure 3 show that interactions among resources also produced important effects on sortie percent. For instance, the data show that percent sorties accomplished across spares levels increased faster as more and more AIS became available (slope increases across panels). This result suggests that the more spares there were on hand, the greater the flying rate, but unless repair facilities for failed LRUs were available, spares were exhausted rapidly and overall sortie percent peaked at a level far below what is required for a UR 135 scenario. When AISs were provided, a constant flow of repaired LRUs could restock spares supplies and help sustain heavy flying demands.

However, the relationship among resource levels is more complicated. A three-factor interaction between manpower, spares, and support equipment is evident in Figure 3. The separation among graphs across panels is greater at the higher than at the lower spares levels. Sortie percents were poor at the low spares levels, and even drastic increases in manpower and support equipment could not compensate for low initial supplies. However, at higher spares levels, more personnel and AISs "paid off" in the sense that these resources boosted sortie percents when initial spares inventories were plentifully stocked.

These data demonstrate the complex relationships among flying activity and resource levels that prevail in O&M environments. Higher resource levels yield higher overall sortie rates, resulting in more failures and more demands for resources. If supplies are on hand, or can be regenerated in large numbers, then activity is sustained. But once initial spares levels are exhausted, further sorties (a) continuously drain whatever repaired LRUs are generated, and (b) create massive backlogs of failed parts that cannot be repaired quickly enough to stem the decline of flying activity. Before examining repercussions of resource levels and flying activity on other LCOM measures, it is useful to examine daily variations in sortie percent among our simulations.

Figure 4 depicts in nine panels all combinations of the resource quantities as they influenced Percent Sorties Accomplished over the surge period. Sortie percents were averaged into six successive blocks of 5 flying days each for clarity of presentation. The top, middle, and bottom rows of panels represent sortie percent under manning levels of 1572, 972, and 781 personnel, respectively. The left, middle, and right columns of panels present the 0, 1, and 2 AIS conditions, respectively. Within each panel, the four spares levels are differentiated by graph lines.

Figure 4 provides clear evidence that a surge scenario cannot be sustained unless resources are set initially at relatively high levels. For instance, in the bottom left-hand panel, the solid-line graph represents the flying rate accomplished under the worst of the resource conditions--463 LRUs, 781 personnel, and no AIS. As can be seen, flying activity dropped from 60% in the first 5 days to only 13% in the last 5 days. Obviously the overall UR 135 could not be satisfied under these

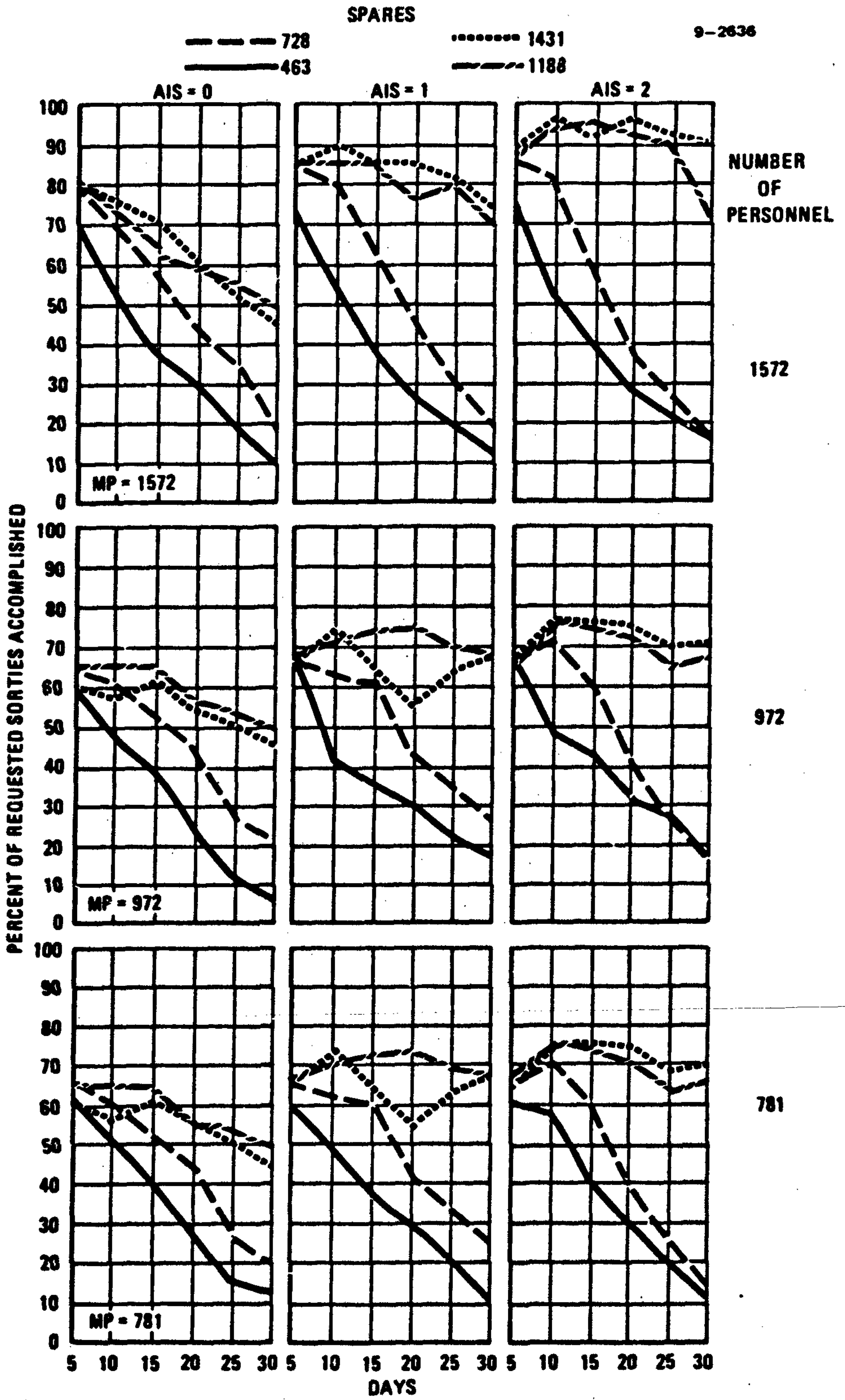

FIGURE 4 PERCENT SORTIES ACCOMPLISHED FOR ALL RESOURCE CONDITIONS IN SIX BLOCKS OF FIVE DAYS EACH

conditions; in fact, the actual UR accomplished was about 45 sorties per aircraft per month, one-third of the requested rate. And it should be kept in mind that this decline in flying activity was solely the product of deficiencies in the maintenance environment. In all simulations, it was assumed that aircraft would not be lost to battle damage, environmental conditions, or other sources of attrition. Within the same panel of Figure 4, increases in spares levels slowed the decline in sortie percent so that in the best of these poor support conditions--1431 LRUs, 781 personnel, and no AIS--UR peaked at slightly over 75 sorties per aircraft per month.

The remaining eight panels of Figure 4 generally show that the most influential resource for sustaining heavy flying demands was initial spares supplies. In all nine panels, sortie rate was sustained longer and at higher levels as more spares were provided. As shown in the 30-day average data, the two highest spares conditions of 1188 and 1431 LRUs did not yield very different sortie percentages when daily trends were examined. Each panel shows that the highest spares conditions, sustained flying activity about equally well. (As will be noted in subsequent regression analyses, this lack of further improvement with changes in spares lowers the predictive strength of a model that includes spares level as an independent variable.)

Figure 4 also reveals the effects of manpower, support equipment, and interactions between all resources on sortie percentages. The effect of manpower is seen by comparing measures in rows of panels, and this exercise shows that as manpower increased, there were average gains in sortie percent. However, the shapes of the separate curves over days and the differences between curves did not vary much. Similarly, a comparison across columns indicates that adding more AIS improved performance generally, but did not greatly influence daily change patterns.

The three-factor interaction among manpower, spares, and support equipment again was apparent in the daily performance changes. It may be noted in Figure 4 that for all spares levels, the first 5-day value of Percent Sorties Accomplished was larger as more personnel and more support equipment were provided. However, at the two lowest spares levels, flying rates declined rapidly over the 30 days regardless of the manpower and support equipment available. On the other hand, the two highest spares levels were augmented by the other two resources so that declines in flying rates were actually halted and sortie percent held at relatively high levels across the 30 days (see Figure 4, top left panel). For the best resource conditions--1431 spares, 1572 personnel, and 2 AISs--the accomplished UR totaled approximately 122 sorties per aircraft per month which, although significantly lower than the requested UR 135, was controlled in part by aircraft and flying window restrictions.

To summarize the Percent Sorties Accomplished measure, clear effects due to spares levels and marginal effects due to manpower and support equipment were found. Flying activity was held constant over

days when initial spares levels were high and sufficient manpower and equipment were available to repair failed LRUs and provide a consistent flow of spares back into supply. However, when quantities of any of the three resources were relatively low, flying activity rapidly deteriorated to alarmingly low levels over the surge days. Some tradeoffs between resources were identified based on various two- and three-factor interactions. For instance, when no AISs were available, as would be the case in a remote deployment of aircraft, relatively high spares levels offset the maintenance capability lost when limited manpower was available. On the other hand, when manning levels where increased by slightly more than a factor of two, this produced virtually no improvement in ability to sustain the flying demands when very few spares were allocated.

In the present simulations, flying activity was requested by mission types and each type required a minimum number of aircraft be available. If the minimum number could not be filled, the mission was cancelled. Thus, if a four-aircraft mission was cancelled because only two aircraft had been available, then two LCOM measures reflected this loss--Percent Missions Accomplished and Percent Sorties Accomplished. In the present example, one mission was lost and four sorties were lost in the same cancellation. If the same mission were requested and three of four aircraft satisfied the minimum aircraft conditions, then the mission would have been flown, and the same two LCOM measures would have been differentially affected. In this case, the mission would not be lost, but one sortie (three out of four requested were flown) would have been lost. The relationship between missions and sorties has two consequences for analysis: (a) unless all missions and sorties are accomplished, there will always be a higher percentage of missions accomplished than sorties accomplished; and (b) effects attributable to resource manipulations will be nearly identical for the measures because the two are highly correlated. Indeed, the analyses showed that spares, manpower, and support equipment influenced mission rates in the same directions and magnitudes as they influenced sortie rates.

The resource quantities contributed to variations in the Aircraft category of measures (see Table 1), and two of those measures are considered here for their close relationship to sortie percentages and for their importance to assessments of "readiness," an issue of concern to Air Force planners. The status of a given aircraft can be described in several mutually exclusive classifications. For example, the aircraft might be flying a sortie or waiting to take off; it may be in maintenance or in a pool of available aircraft. LCOM accumulates the percentage of time each aircraft resides in these status classifications in terms of the total "aircraft-days" available. Aircraft-days is simply the product of aircraft and flying days and for these simulations equaled 2160 aircraft-days (72 A/C x 30 days). Measures 15 through 21 listed in Table 1 represent percent of aircraft-days and always total 100% in a given simulation.

Of particular importance to this investigation were Percent in Non-operationally Ready Supply (NORS) and Percent Operationally Ready (OR). [Note: Current aerospace vehicle status codes, such as Full Mission Capable (FMC), Partial Mission Capable (PMC), etc., have not been incorporated in the LCOM (Reference 4)]. An aircraft is in NORS status when insufficient spares supplies are available to repair one or more failed LRUs that are required for the aircraft to be mission-worthy. The OR status is, in a sense, the opposite of the NORS status; in OR an aircraft is fully prepared for a mission. With respect to readiness, low NORS and moderate to high OR rates are signs that the wing is prepared for combat. On the other hand, high NORS and low OR rates suggest lowered readiness and signal potential problems for sustaining a surge operation.

Figure 5 presents both the NORS and OR rates as a function of resource levels studied, and these results highlight readiness deficits when resource levels are severely constrained. Each data point represents a 30-day average for the appropriate condition. As can be seen, spares quantities controlled both NORS and OR rates, whereas manpower and support equipment made only small additional contributions to variations in these measures. In the lowest spares condition, NORS reached and exceeded 60%, and OR remained near 10%, regardless of added manpower or support equipment. These rates signal limited capacity to maintain the surge requirement. However, as more spares were allocated, NORS dropped rapidly and OR rose slowly but steadily. The reason for the difference in these rates of change becomes obvious in light of Figure 3--as NORS drops, more aircraft are available to fly missions, and, therefore, "Percent on Sorties" increases to as high a level as failure rates will allow.

Figure 6 illustrates the NORS rate changes as a function of days in each simulation. A comparison of these data with those in Figure 4 on sortie percentages shows the high negative correlation between these measures. Generally, as more sorties were flown and more failures were generated, spares supplies were quickly exhausted and aircraft were routed to a NORS status. In the lowest spares conditions, the NORS percentage increased rapidly over days, and after 30 days approximated 90% independent of other resources. However, when spares were increased, the time which aircraft remained in the NORS status was reduced.

There was an interaction between AIS level and spares quantity across days, and this is most easily seen by comparing the NORS rates for the highest spares conditions in the left and middle columns of panels in Figure 6. Notice that with one AIS, NORS increased over days at a slower rate than when no AIS were available. This result shows that support equipment which is used to repair spares can regenerate sufficient supplies to keep NORS at acceptable levels.

Once an aircraft was in the NORS status it was vulnerable to cannibalization. Therefore, a close relationship might be expected between NORS percentage and frequency of cannibalizations. However, several

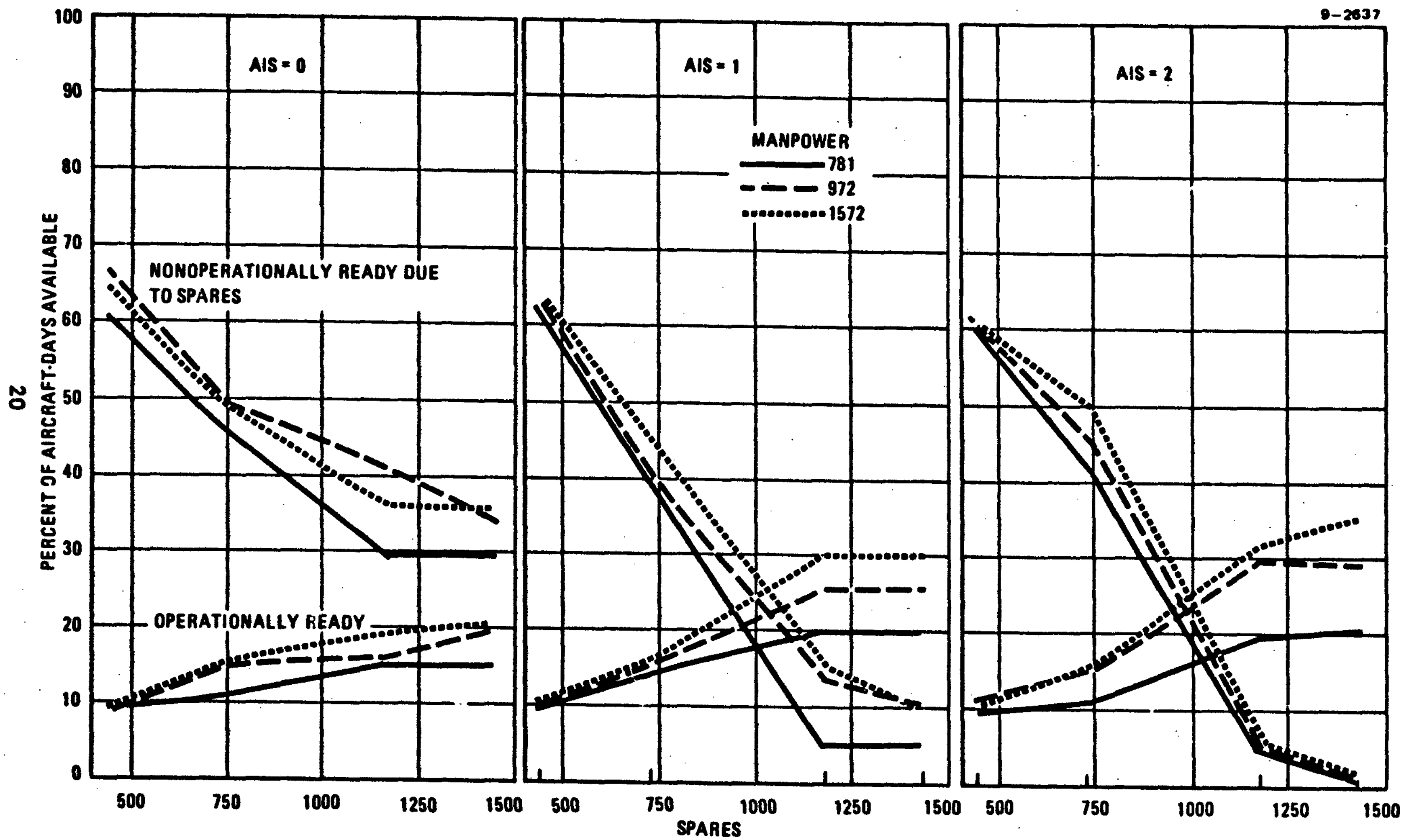

FIGURE 5 PERCENT OF AIRCRAFT-DAYS AVAILABLE IN NONOPERATIONALLY READY AND OPERATIONALLY READY STATUS AVERAGED OVER DAYS FOR ALL LEVELS OF SPARES, MANPOWER, AND SUPPORT EQUIPMENT

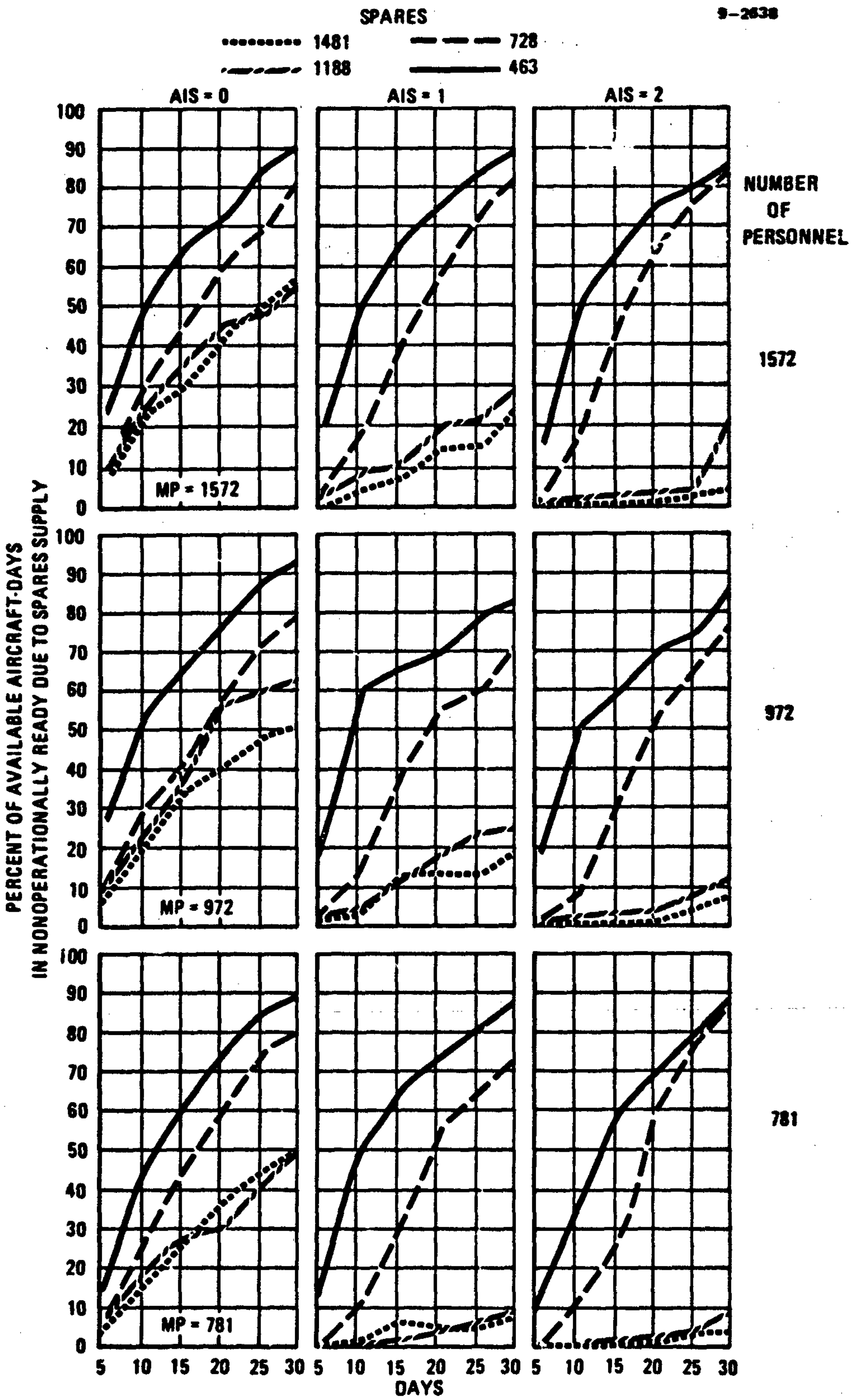

FIGURE 6 PERCENT OF AIRCRAFT-DAYS IN NON-OPERATIONALLY READY DUE TO SPARES SUPPLY FOR ALL RESOURCE CONDITIONS IN SIX BLOCKS OF FIVE DAYS EACH

additional considerations complicate what appears to be a simple relationship. First, any factor which helps replenish supplies should work to keep cannibalizations as well as NORS rate low. As described previously, providing AIS maintains LRU repair activity and slows the NORS rate. Therefore, cannibalization should be less frequent when more support equipment is available. Second, cannibalization requires manpower; functional LRUs can be obtained from disabled aircraft only if people are available to perform these tasks. Thus, the greater the manpower levels on the average, the more cannibalizations should occur. Third, flying activity increased NORS levels dramatically when spares were low initially (Figure 6), and across 30 days, there was no improvement or reversal in NORS. This relationship implies an interesting outcome for cannibalization frequency. Given low spares levels, cannibalizations should increase across days as NORS increases. But cannibalization itself exacerbates the NORS rate by further impairing an aircraft's potential availability; parts taken from an aircraft almost ensure it will remain in a permanent NORS status. Therefore, cannibalization should peak and then decline over days as the system, in a sense, consumes itself.

Figure 7 shows the total cannibalizations performed per 5-day block in each simulation, and each of the effects described above can be seen in these data. First, the more spares provided initially or made available by the introduction of AIS, the lower the overall frequency of cannibalizations. Second, more cannibalizations were performed at the higher manpower levels (compare rows of panels from bottom to top). Finally, over the 30 days, cannibalizations tended to increase to a peak frequency and then decline to relatively low levels.

Changes in several additional Shop Repair, Supply, and Equipment category measures were examined, and graphs of these data appear in Appendix E of this report. Rather than elaborate on each measure, the reader is referred to this appendix for further examination of these data. Generally, each measure revealed a sizable effect due to spares supplies and lesser effects due to manpower and support equipment. The relationships between changes in flying activity and changes in Shop Repair, Supply, and Equipment measures corroborate the mutual dependence of activities that drive these measures. For instance, flying activity produces failures and failures produce demands for supply units, support equipment units, and cannibalizations. Failures also create work for shop repair, and therefore, generations of LRUs increase and decrease with failure rate.

Finally, a number of measures showed significant effects of manpower levels, and several of these are presented here to elucidate where manning levels influenced system performance. First, when an aircraft returns from a sortie, complete maintenance checks are initiated, failed LRUs are identified, and unscheduled maintenace is performed prior to the aircraft being routed to OR. Obviously several factors influence the amount of time an aircraft spends in post-sortie maintenance,

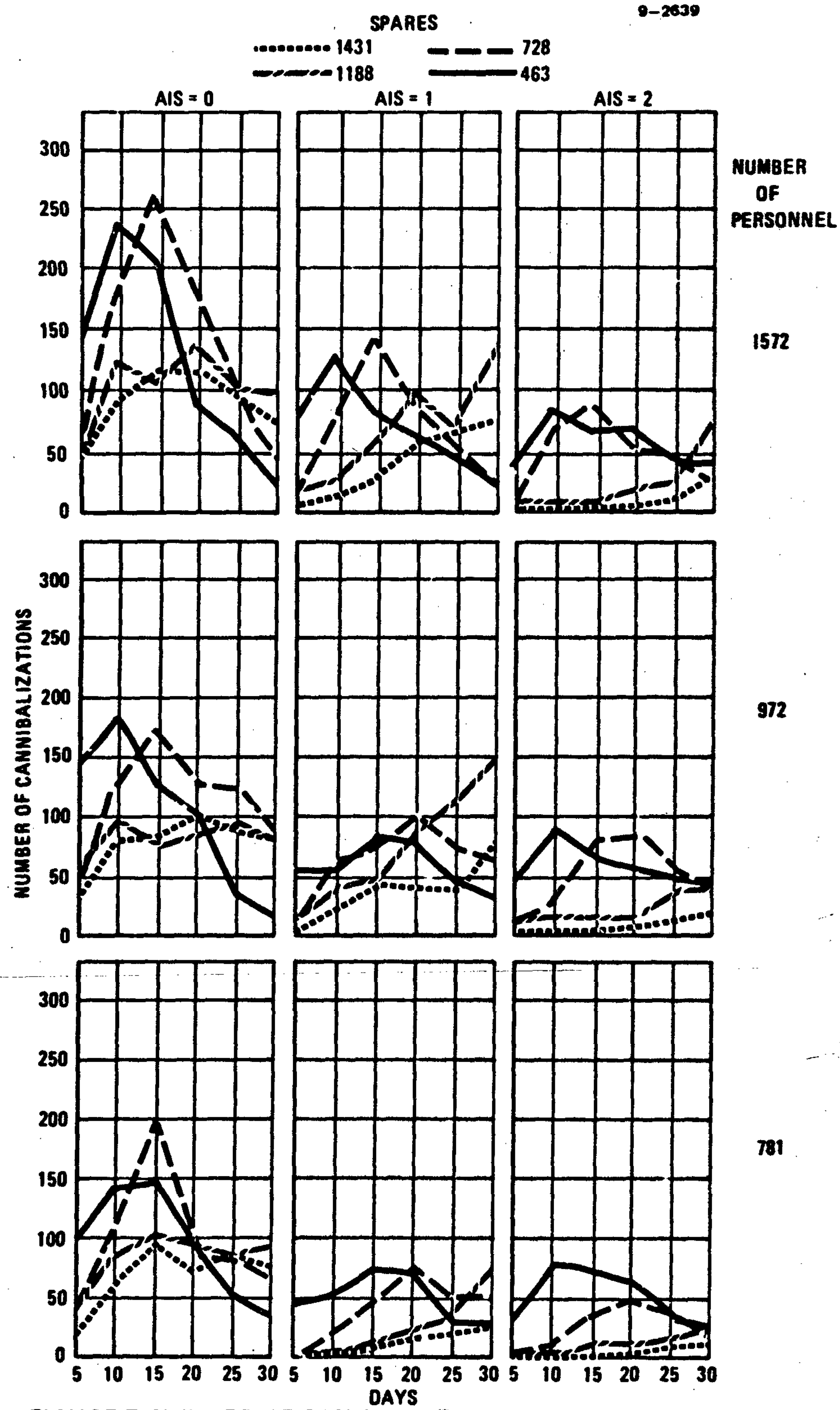

FIGURE 7 NUMBER OF CANNIBALIZATIONS FOR ALL RESOURCE CONDITIONS IN SIX BLOCKS OF FIVE DAYS EACH

including equipment needs and availability, skill level of the technician(s) performing the maintenance, and severity of the damage. The present simulations did not examine all potential source of turnaround time variability, but it appears that manpower levels made a major contribution to Average Aircraft Post-sortie Time (Figure 8). Very simply, the more personnel available, the more rapidly aircraft were serviced and readied for another sortie.

The AIS and spares levels appeared to make little or no contribution to changes in post-sortie time. This conclusion is too simplistic, however, given the data concerning sortie and NORS rates. Post-sortie time is computed for aircraft that have completed processing and, therefore, can be based on different numbers of turnarounds in different simulations. A better understanding of the impact of resource quantities on post-sortie time must take this computational procedure into account. For instance, cannibalized aircraft that never exit a NORS status do not contribute a value to average post-sortie time. Figure 8 shows simply that speed of repair for aircraft that were eventually repaired and sent to OR was a function of the number of maintenance personnel available.

In the Personnel category, several measures showed a dependence of manpower use on spares supply and flying activity. The data of primary interest are illustrated in Figures 9 through 12. In Figure 9, it can be seen that the Number of Personnel Demanded was an increasing function of spares supplies, which as we have noted, was in turn related to sortie percentages. As with other LCOM measures, there was a circular cause-and-effect arrangement between manpower demands and flying activity.

Figure 10 shows generally that the Percent of Personnel Demanded that Was Not Satisfied remained relatively low across all resource conditions, but was a decreasing function of manning level. The selection of manning levels had been guided by expected use and obviously yielded levels that were higher than necessary. Since nearly all demands were satisfied for the highest manning conditions, the contribution of the manpower variable to predictive models was expected to be lower than if many demands had not been satisfied. That is, the problem here is a ceiling effect that lowers the correlation between an independent variable and LCOM performance measures.

The final two measures presented, Total Manhours Used (Figure 11) and Simulated Manhours per Flight Hour (Figure 12), show (a) that there was a positive relationship between personnel used and flying activity that was mediated by spares supply and (b) that, under high flying rates, proportionally fewer manhours were generated per flight hour.

To summarize, the experimental findings of the present simulations showed that resource quantities and interactions among resources produced wide variations in LCOM measures of F-15 performance. Of the resource variables examined, spares supplies tended to contribute most to the experimental effects. However, it was suggested that the levels

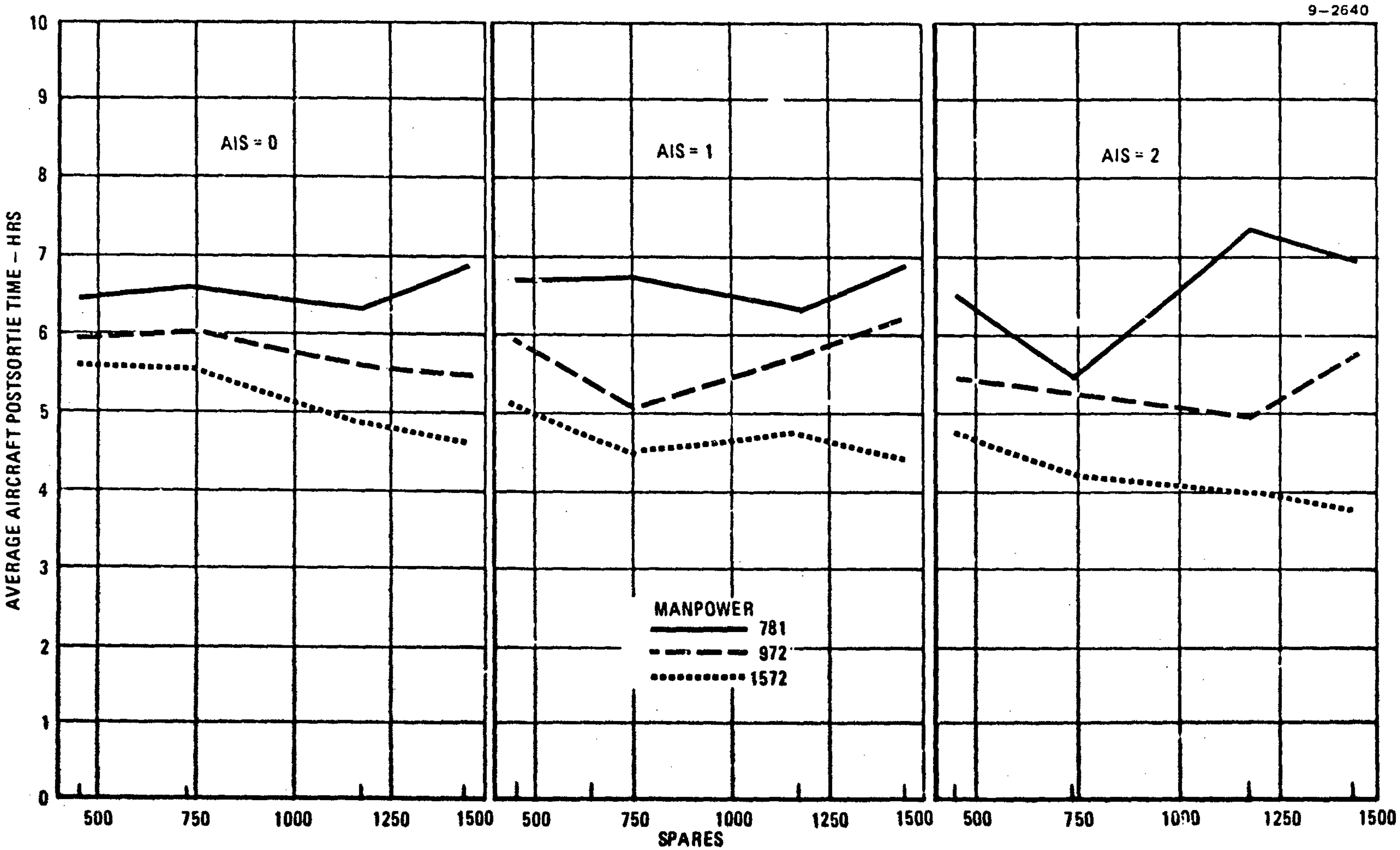

FIGURE 8 AVERAGE AIRCRAFT POST-SORTIE TIME AVERAGED OVER DAYS FOR ALL RESOURCE CONDITIONS

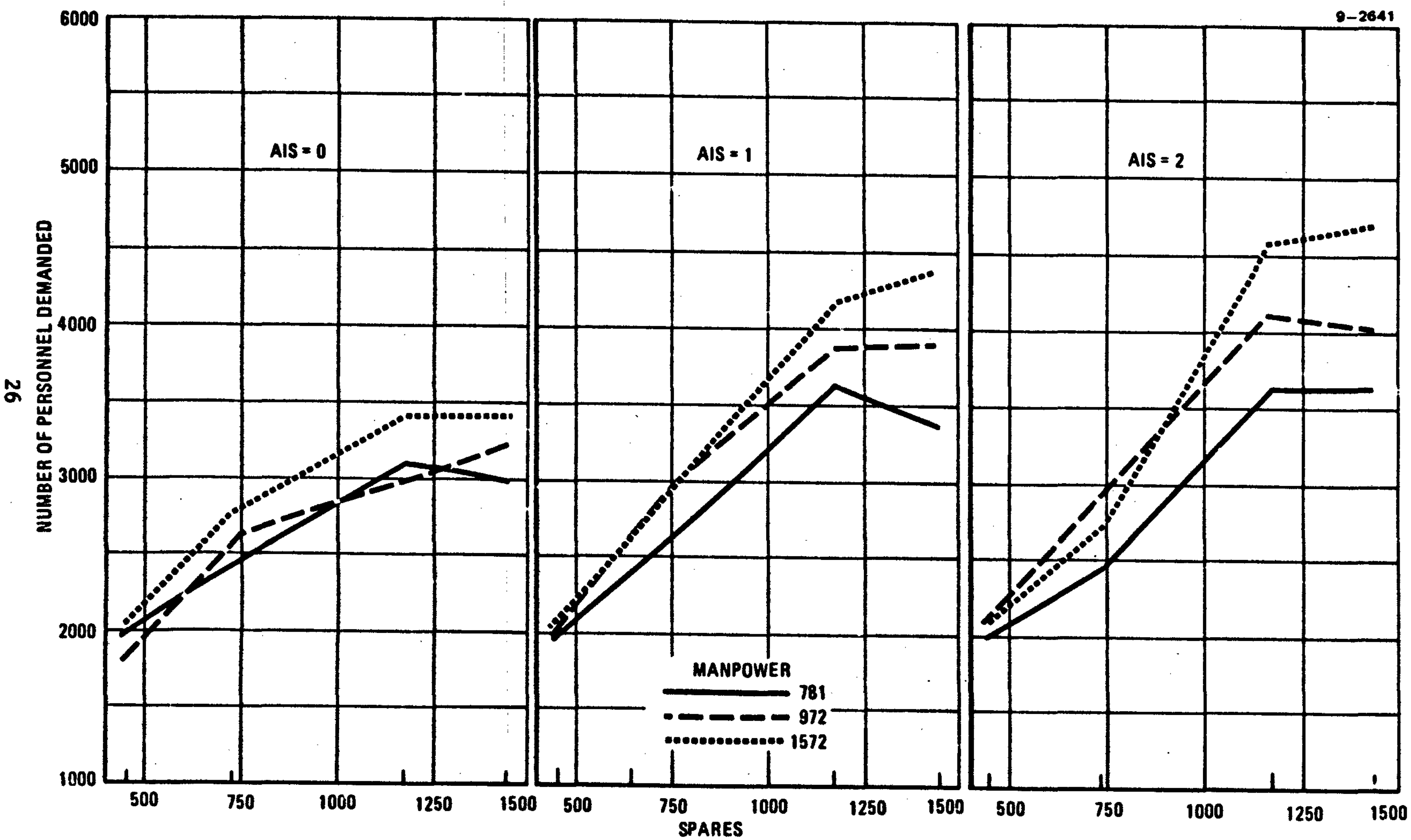

FIGURE 9 NUMBER OF PERSONNEL DEMANDED TOTALED OVER DAYS FOR ALL RESOURCE CONDITIONS

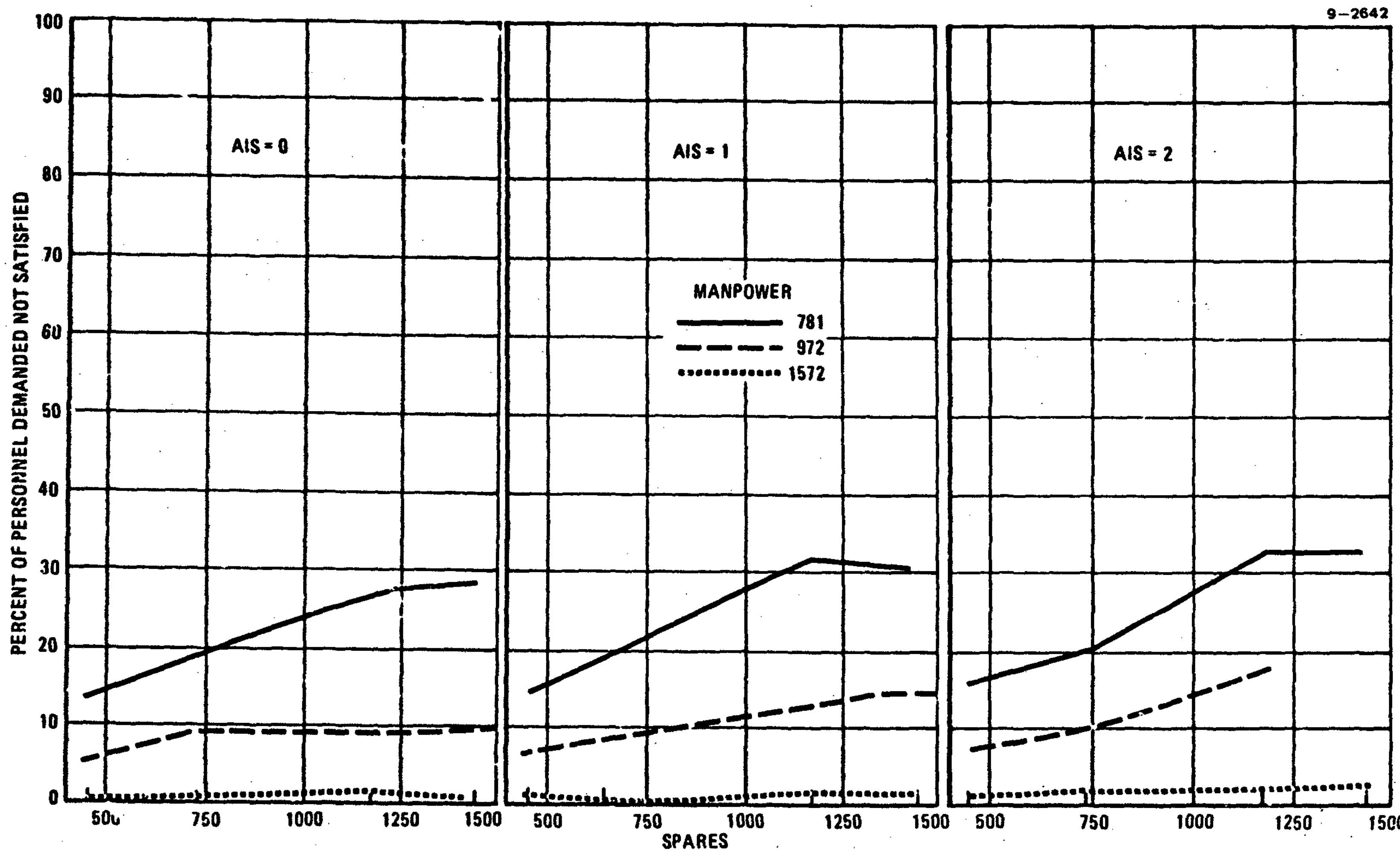

FIGURE 10 PERCENT OF PERSONNEL DEMANDED NOT SATISFIED AVERAGED OVER DAYS FOR ALL RESOURCE CONDITIONS

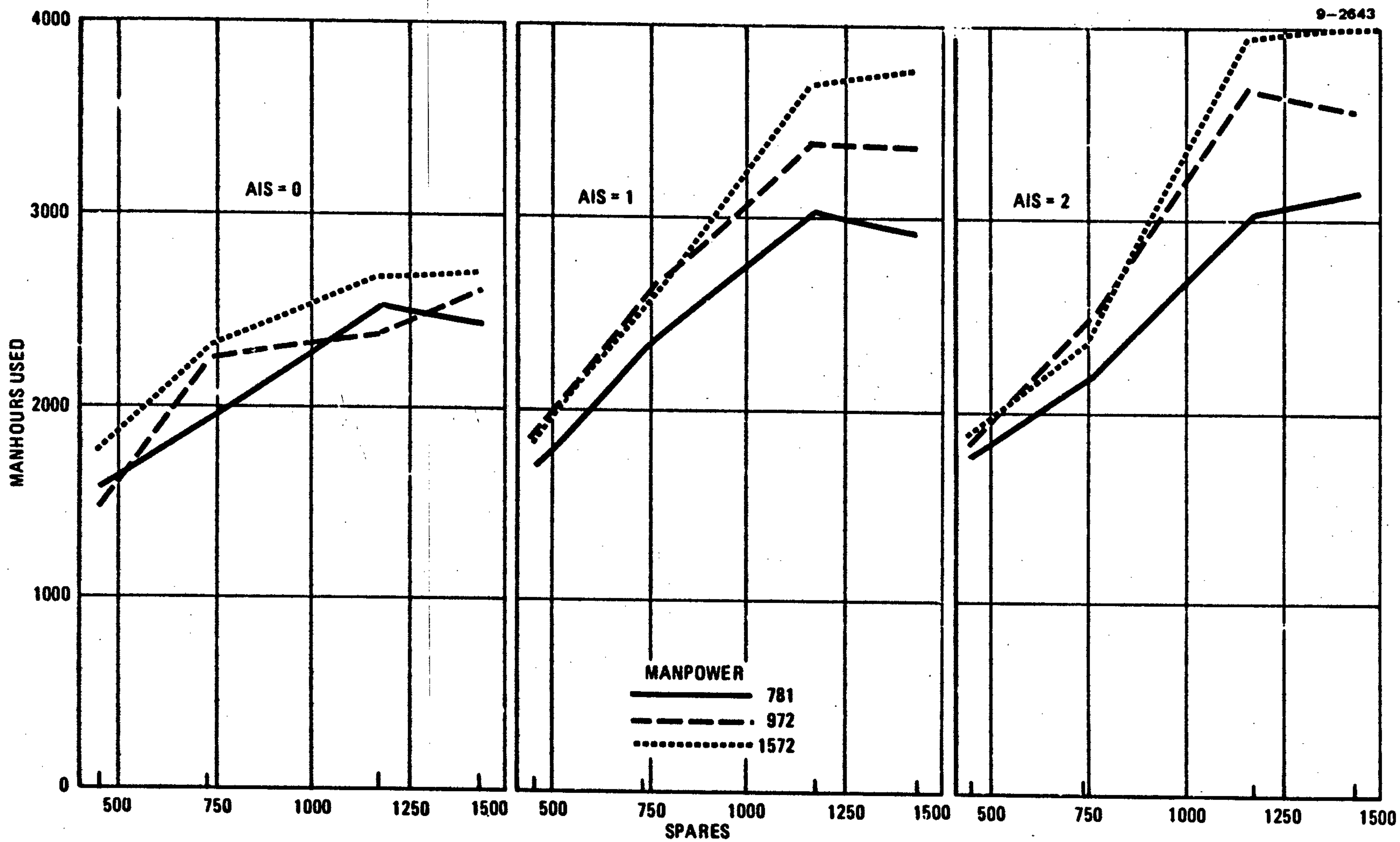

FIGURE 11 MANHOURS USED TOTALED OVER DAYS FOR ALL RESOURCE CONDITIONS

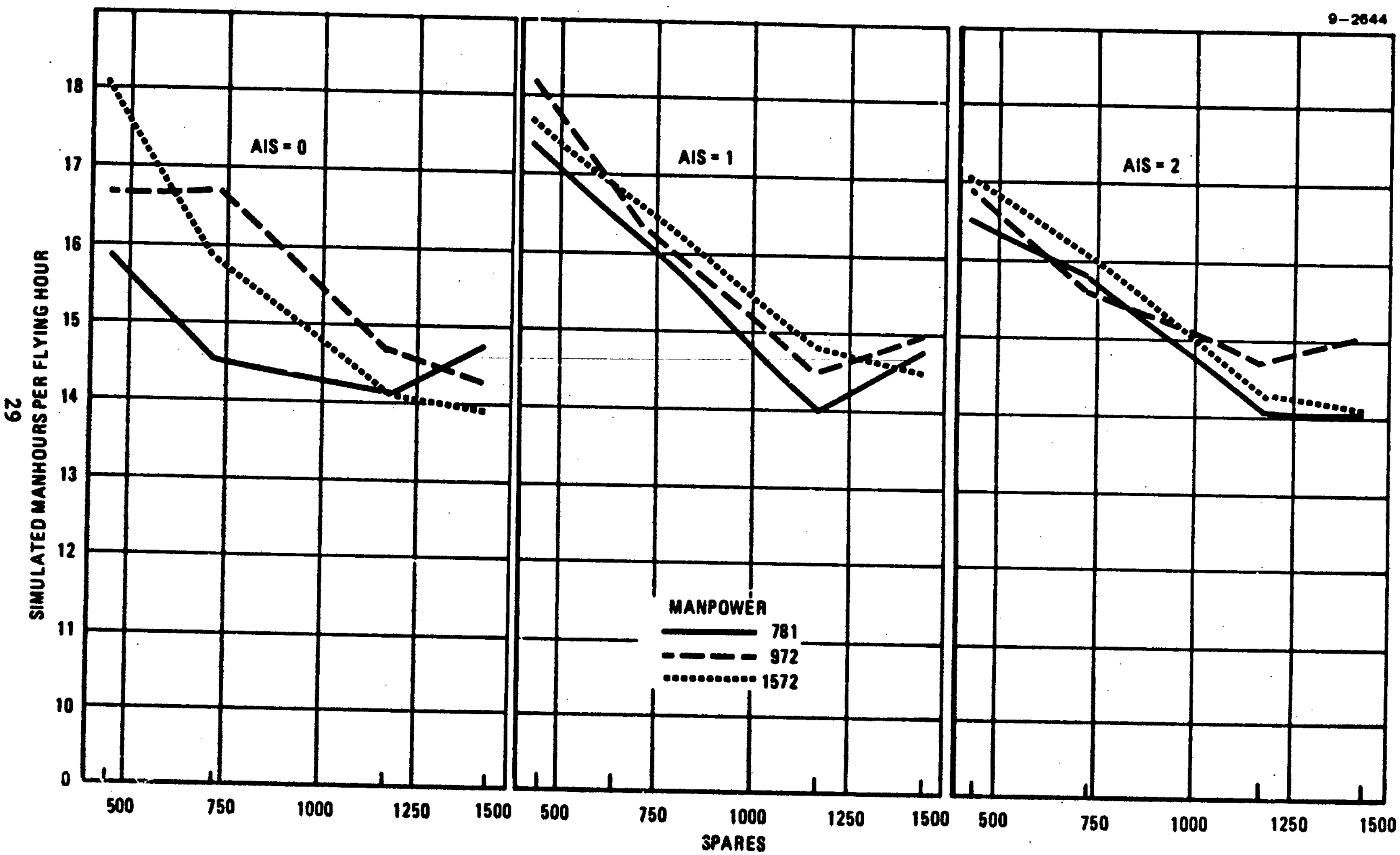

FIGURE 12 SIMULATED MANHOURS PER FLIGHT HOURS AVERAGED OVER DAYS FOR ALL RESOURCE CONDITIONS

of each resource controlled the impact of the variable, and therefore, effect magnitudes and eventually predictive models generated from the present data need to be interpreted with these limitations in mind. Generally, manpower and support equipment contributed to performance variations, but levels of both of these variables tended to be too high to allow more substantial effects to emerge. This observation should serve to alert users of simulation modeling techniques to the fact that output measures of system performance are not sensitive to resource limitations if most demands for resources are easily satisfied. In the present simulation, only spares levels adequately sampled a broad enough range to yield truly sensitive performance differences. However, these results are encouraging since relatively small effects associated with levels of manpower and equipment suggest that even lower quantities can be expected to produce relatively good performance.

REGRESSION MODELS

Predictive models for each of the 40 LCOM measures are presented in complete detail in Appendices F through G. As mentioned earlier, two models were generated per measure, one that included selected Days components as predictive terms and a second that treated all variations over Days as error. First, there is an example of a regression model for Percent Sorties Accomplished. Following an explanation of how this model can be used, the models developed for the remaining LCOM measures are summarized and evaluated.

As Figures 3 and 4 show, Percent Sorties Accomplished varied as a function of resource quantities. The variation in this measure can be conceptualized as a unit circle the area of which equals the total sum of squared deviations around the mean of Percent Sorties Accomplished. Regression analysis then partitions this variability among the factors manipulated by the experimenter. As mentioned in the Approach section, the two analyses conducted here included 26 and 80 factors, respectively, based on exclusion or inclusion of Days as a factor. Table 3 summarizes the variance distribution among 26 factors in the first analysis type for Percent Sorties Accomplished. The percentage of variance and regression coefficient attributed to each factor are listed along with total accounted variance and subtotals for the main factors and interactions. Figure 13 subtotals for the main factors and interactions. Figure 13 illustrates the partitioning of the total variance derived from the first type of analysis.

As Table 3 indicates, only 5 of the 26 single degree-of-freedom (df) factors accounted for sufficient variance to satisfy the significance test criteria that were adopted. This does not mean that the remaining 21 factors contributed nothing to total variance, only that the criteria effectively screened out factors that made very small contributions. A second point to note is that the total variance accounted for by the 26-factor model was relatively low, 51.45%. In regression analysis, effects due to all single df factors always sum to 100% of the variance. But one objective of regression analysis is to account for as much variance with as few factors as possible so that the final predictive model is a parsimonious one. Evidently the 26-factor model, while relatively parsimonious (1079 single df factors were possible), was not a powerful model since the proportion of unexplained variance was large, 48.55%.

An examination of the variance percentages for individual factors shows a good correspondence between the predictive model and the relative effect magnitudes seen in the experimental findings (see Figure 3). It was found that spares supply appeared to have the greatest effect on Percent Sorties Accomplished among the resources examined. As Table 3 shows, the two single df factors associated with the Spares main effect accounted for 42.69% of total variance, and nearly 83% (42.69/51.45) of the variance accounted for in the model. The second largest effect was due to Support Equipment, and Manpower made the smallest contribution

9–2645

PERCENT ACCOMPLISHED – SORTIES

VARIABLE 08 = 55.9077 + 29.4092 (S) + 9.439 (M) + 5.7461 (SE) – 30.6195 (S^2) + 63.3809 (S X M^2 X SE)

TOTAL VARIANCE (R^2) = 51.45
STANDARD ERROR OF ESTIMATE = 15.71

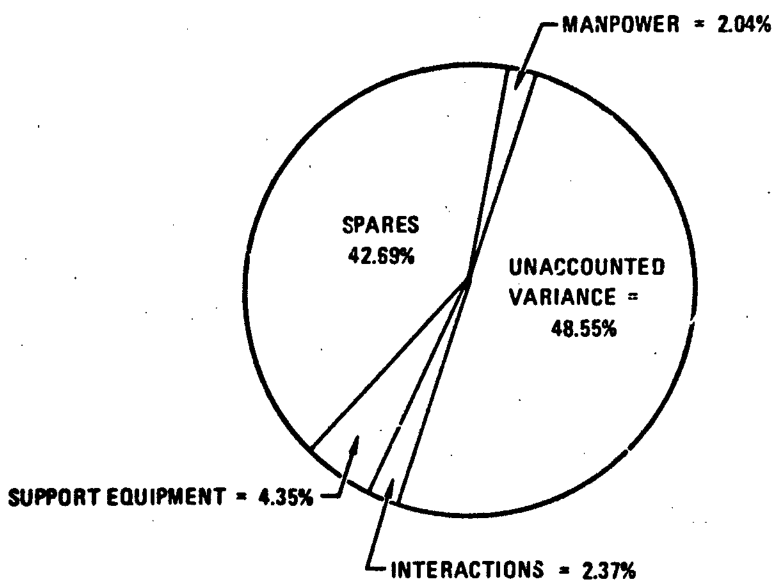

FIGURE 13 DISTRIBUTION OF VARIANCE IN PERCENT SORTIES ACCOMPLISHED DUE TO A REGRESSION MODEL BASED ON MANPOWER, SPARES, AND SUPPORT EQUIPMENT

TABLE 3 DISTRIBUTION OF VARIANCE AND REGRESSION COEFFICIENTS FOR 26 FACTORS DERIVED FROM COMPONENTS OF SPARES, MANPOWER, SUPPORT EQUIPMENT, AND INTERACTIONS FOR PERCENT SORTIES ACCOMPLISHED

PREDICTOR	PERCENTAGE OF TOTAL VARIANCE	REGRESSION COEFFICIENT
	-	55.9077 (Intercept)
1. Manpower - linear (M)	2.04	9.4359
2. - quadratic (M2)		
3. Spares - linear (S)	40.98	29.4092
4. - quadratic (S2)	1.71	-30.6195
5. Support Equip. - linear (SE)	4.35	5.7461
6. - quadratic (SE2)		
7. M x S		
8. M x S2		
9. M2 x S		
10. M2 x S2		
11. M x SE		
12. M x SE2		
13. M2 x SE		
14. M2 x SE2		
15. S x SE		
16. S x SE2		
17. S2 x SE		
18. S2 x SE2		
19. M x S x SE		
20. M x S x SE2		
21. M x S2 x SE		
22. M x S2 x SE2		
23. M2 x S x SE	2.37	63.3809
24. M2 x S x SE2		
25. M2 x S2 SE		
26. M2 x S2 x SE2		
Number of Predictors in Equation	5	
% Variance Accounted for	51.45	
Variance Subtotals		
Manpower	2.04	
Spares	42.69	
Support Equipment	4.35	
2-Factor Interactions		
3-Factor Interactions	2.37	
Standard Error of Estimate		15.71

among main effects. One component of the three-factor interaction among Manpower, Spares, and Support Equipment contributed a sufficient percentage of variance to satisfy the significance test criteria, and this supports the earlier observation of such an effect. None of the two-factor interaction components were of sufficient statistical importance to be included in the final model.

The first analysis yielded a linear equation that uses the quantitative levels of resources weighted by the appropriate regression coefficient and produces an expected value of Percent Sorties Accomplished. The equation for this measure was

$$\% \text{ Sorties Accomplished} = 55.9077 + 9.4359(M) + 29.4092(S) - 30.6195(S^2) + 5.7461(SE) + 63.3809\ (S \times M^2 \times SE)$$

where M refers to manpower level, S to spares level, and SE to support equipment level.

To derive these models, the manpower and spares levels were transformed prior to computing regression coefficients because the magnitudes of some quadratic terms and interactions became so large that precision was lost. For instance, with the largest manpower and spares levels, 1572 and 1431, respectively, the quantitative value of the $M^2 \times S^2$ interaction would have been $1572^2 \times 1431^2 = 5.06039... \times 10^{12}$. In regression analysis, rounding yields imprecision in coefficients which becomes more severe as more steps are computed. Therefore, 949.5 was subtracted from each manpower level, 1109.667 from each spares levels, and then each result was divided by 1000 prior to using the levels as correlates with values of a performance measure. It should be emphasized that this procedure in no way changes the predictive fidelity of these models. The proper use of the equation listed above in the previous paragraph for predicting sortie percentages requires that the transformations be performed before levels are entered into the equation.

For example, if the user wanted to know the expected sortie percent for 30 days given resource quantities of 1200 personnel, 900 LRUs, and 2 AISs, the two transformations are performed first; then the equation is solved:

$$\text{Manpower} = (1200 - 949.5) \times .001 = .2505$$
$$\text{Spares} = (900 - 1109.667) \times .001 = -.209667$$

$$\% \text{ Sorties Accomplished} = 55.9077 + 9.4359(.2505) + 29.4092(-.209667) - 30.6195(-.209667^2) + 5.7461(2) + 63.3809\ [(.2505^2)\ (-.209667)\ (2)] = 60.6\%$$

Approximately one-half of the sorties requested in a UR 135 schedule would be expected to occur under these resource conditions according to the model. It should be clear that this value is an estimate for 30 days and that daily expected percents would not be available with such a model. Furthermore, since the model accounted for only 51.45% of the

variance in observed sortie percentages, the 60.6% estimate derived from the model is subject to error. On the average, that error is rather large as can be deduced from a standard error of estimate value which equaled 15.71% (see Table 3). The standard error indicates that in the long run, approximately two-thirds of the sortie percents actually observed under the assumed resource conditions would fall within ±15.71% of 60.6%. Needless to say, this is a relatively poor predictive device.

A much superior predictive device was obtained when the linear and quadratic components of Days were included as main factors and in interaction with the 26 factors of the first analysis. The analyses that included Days tested 80 single df effects, a relatively simple model considering that 1079 effects were potential candidates. Due to space limitations, Table 4 lists the descriptors, percentages of variance, and regression coefficients for those factors among the 80 that satisfied the significance test criteria for the second model. Appendix G presents each factor tested.

As Table 4 shows, the predictive model became more complex when Days components and interactions were added. The number of terms in the final equation rose from 5 to 22. But the added complexity yielded a much more powerful prediction device, accounting for a total of 91.08% of the variance and keeping the standard error at ±6.79% of mean values. Furthermore, daily sortie percent values can be computed with this second model, whereas only 30-day average values can be estimated with the first model.

The procedures for using the second model are identical to those just described, with one addition. A Day value is required. The Day value transformation is first computed using the following formula:

$$D = \text{Day} - 15.5$$

Table 5 presents a comparison of the observed sortie percents for each of 30 days in two different simulations, and the predicted percents generated by the second model. Inspection of the "Difference" column shows that there were many discrepancies between observed and predicted results, but generally they were within tolerable levels. Recall that these are stochastic models designed to predict performance assuming large variations in resource levels. In light of the dramatic performance changes obtained (see Figure 4), the present equation predicted the results remarkably well given its relative simplicity. In both comparisons shown in Table 5, the model accurately predicted general trends in sortie percents over days. A note of caution is in order. The present equations are valid only for resources levels that fall within the bounds of the levels used to derive the equations. No guarantees can be made about predictions when resources levels either underrun or overrun the original levels used in simulations. This may be an obvious, but important, caveat.

TABLE 4 DISTRIBUTION OF VARIANCE AND REGRESSION COEFFICIENTS FOR 80 FACTORS DERIVED FROM COMPONENTS OF SPARES, MANPOWER, SUPPORT EQUIPMENT, DAYS, AND INTERACTIONS FOR PERCENT SORTIES ACCOMPLISHED

PREDICTOR	PERCENTAGE OF TOTAL VARIANCE	REGRESSION COEFFICIENT
		55.9805 (Intercept)
1. Manpower - linear (M)	2.04	6.7818
2. Spares - linear (S)	40.98	27.7055
- quadratic (S2)	1.71	-38.6294
3. Support Equipment - linear	4.36	14.2978
- quadratic (SE2)	0.49	-2.8850
4. M x S	0.34	11.2481
5. M x SE	0.10	4.0377
6. M2 x SE	0.16	-16.3688
7. S x SE	0.39	19.1699
8. S x SE2	0.16	-5.0227
9. M x S x SE	0.10	8.6186
10. M x S2 x SE	0.13	11.0326
11. M2 x S x SE	2.36	11.4445
12. Days - linear (D)	26.18	-1.5051
13. M x D	0.56	-0.5717
14. S x D	8.82	1.4033
15. SE2 x D2	0.18	-0.0154
16. M2 x S x D2	0.43	-0.3544
17. S x SE x D	0.59	0.4086
18. S2 x SE x D	0.58	1.1922
19. S2 x SE2 x D2	0.32	0.0642
20. M2 x S x SE x D	0.10	1.9431
Number of Predictors in Equation	22	
% of Variance Accounted for	91.08	
Variance Subtotals		
Manpower	2.04	
Spares	42.69	
Support Equipment	4.85	
Days	26.18	
2-Factor Interactions	10.71	
3-Factor Interactions	4.51	
4-Factor Interactions	0.10	
Standard Error of Estimate		6.79

TABLE 5 COMPARISONS BETWEEN OBSERVED AND PREDICTED RESULTS FOR PERCENT SORTIES ACCOMPLISHED PER DAY IN TWO SIMULATIONS

Percent Accomplished-Sorties

$$
\begin{aligned}
\text{Variable 08} = {} & 55.9805 + 27.7055\,(S) + 6.7818\,(M) \\
& + 14.2978\,(SE) - 38.6294\,(S2) - 2.8850\,(SE2) \\
& + 11.2481\,(S \times M) + 19.1699\,(S \times SE) - 5.0227\,(S \times SE2) \\
& + 4.0377\,(M \times SE) - 16.3688\,(M2 \times SE) + 8.6186\,(S \times M \times SE) \\
& + 11.4445\,(S \times M2 \times SE) + 11.0326\,(S2 \times M \times S) - 1.5051\,(D) \\
& + 1.4033\,(S \times D) - 0.5717\,(M \times D) - 0.0154\,(SE2 \times D2) \\
& - 0.3544\,(S \times M2 \times D2) + 0.4086\,(S \times SE \times D) + 1.1922\,(S2 \times SE \times D) \\
& + 0.0642\,(S2 \times SE2 \times D2) + 1.9431\,(S \times M2 \times SE \times D)
\end{aligned}
$$

Total Variance (R2 x 100) = 91.08
Standard Error of Estimate = 6.79

	Resources: 972 Personnel, 735 Spares, 1 AIS			Resources: 972 Personnel, 1431 Spares, 1 AIS		
Day	**Observed**	**Predicted**	**Difference**	**Observed**	**Predicted**	**Difference**
1.	61.54	74.50	-12.96	64.47	87.18	-22.71
2.	73.33	72.64	0.69	77.92	86.62	- 8.70
3.	77.58	70.78	6.80	74.89	86.03	-11.14
4.	83.01	68.90	14.11	82.52	84.43	- 1.91
5.	84.47	67.00	17.47	81.07	84.82	- 3.75
6.	83.01	65.10	17.91	82.04	84.18	- 2.14
7.	82.52	63.19	19.33	82.52	83.53	- 1.01
8.	73.74	61.25	12.54	78.16	82.86	- 4.70
9.	75.24	59.32	15.92	86.41	82.17	4.24
10.	73.30	57.36	15.94	83.01	81.46	1.55
11.	64.08	55.40	8.68	78.46	80.74	- 2.10
12.	57.28	53.42	3.86	81.07	80.00	1.07
13.	59.22	51.43	7.79	68.45	79.24	-10.79
14.	49.51	49.42	0.09	71.84	78.46	- 6.62
15.	50.49	47.40	3.09	73.79	77.66	- 3.87
16.	53.88	45.37	8.51	51.46	76.85	-25.39
17.	44.66	43.33	1.33	51.46	76.02	-24.56
18.	38.35	41.28	- 2.93	55.83	75.17	-19.34
19.	46.60	39.21	7.39	79.61	74.30	5.31
20.	42.72	37.13	5.59	69.90	73.43	- 3.53
21.	50.00	35.03	14.97	72.82	72.52	0.30
22.	41.26	32.93	8.33	80.10	71.61	8.49
23.	43.69	30.81	12.88	76.70	70.67	6.13
24.	38.35	28.68	9.67	77.18	69.72	7.46
25.	31.55	26.54	5.01	69.42	68.74	0.68
26.	34.95	24.38	10.57	74.27	67.75	6.52
27.	34.95	22.21	12.74	69.90	66.75	3.15
28.	29.61	20.03	9.58	76.21	65.72	10.49
29.	26.21	17.84	8.3	72.82	64.68	8.14
30.	30.58	15.63	14.95	74.27	63.62	10.65

Figure 14 illustrates the gain in predictive strength obtained with the second model for Percent Sorties Accomplished. By repartitioning the same data with the new model, the percentage of unaccounted variance dropped from 48.55% (Figure 13) to 8.92%. Furthermore, the two factors which dominated the model in terms of estimating sortie percentage were Spares level and Day of the month. Inspection of Figure 4 shows why these factors were so dominant; sortie percent rose steadily as spares increased but tended to decline across 30 days. The signs of the regression coefficients for the linear components of Spares and Days indicate the positive and negative influences of changes in these factors on sortie percents.

The remaining LCOM measures were predicted with varying degrees of success with the two types of models. Figure 15 shows the partitionings of variance for two of these measures under the two types of models. The circle graphs on the left of the figure represent variance estimates for the Percent of Aircraft-Days in OR, and show that the model without Days components accounted for 48.03% of the variance. In contrast, the model with Days components accounted for 90.72% of the variance an improvement comparable to that of the Percent Sorties Accomplished.

The Number of Cannibalizations was poorly predicted with both models. The circle graphs to the right in Figure 15 show that the proportion of variance unaccounted for with the models was 63.34% for type I and 37.26% for type II. An examination of Figure 7 suggests the reason for the low predictive strength in these models. Across days, the number of cannibalizations tended to increase to a peak value and then decline. The day on which the peak occurred varied across simulations. For a predictive model to be sensitive to this simulation difference, components of the Days factor higher than the quadratic component should have been included. It is difficult to surmise which of the 29 orthogonal Days components would have been best to include as predictive terms, but in retrospect, the linear and quadratic components obviously did not suffice. These observations should serve to caution the user against rigidly adopting a stepwise regression procedure which tests the same components for all performance measures.

Table 6 lists the proportions of total variance accounted for by the two models tested for each of the 40 LCOM measures of interest. (Appendices F through I provide fully elaborated equations and variance portions due to each factor in each model.) Table 6 shows that the models predicted the measures with varying degrees of success. Several models were of high predictive value whereas others were of limited value as evidenced by the wide range of variance figures.

Two shortcomings in the present approach, if corrected, may improve predictive models of LCOM results. First, as was seen in the figures that illustrated the simulation results for several measures (Figures 3 to 12), the choice of resource levels may not have induced variations in performance that were large enough to benefit model development. For instance, in an extreme case some dependent measure may show only small

9–2646

PERCENT ACCOMPLISHED – SORTIES

$$
\begin{aligned}
\text{VARIABLE 08} = \; & 55.9805 + 27.7055\,(S) + 6.7818\,(M) \\
& + 14.2978\,(SE) - 38.6294\,(S^2) - 2.8850\,(SE^2) \\
& + 11.2481\,(S \times M) + 19.1699\,(S \times SE) - 5.0227\,(S \times SE^2) \\
& + 4.0377\,(M \times SE) - 16.3688\,(M^2 \times SE) + 8.6186\,(S \times M \times SE) \\
& + 11.4445\,(S \times M^2 \times SE) + 11.0326\,(S^2 \times M \times S) - 1.5051\,(D) \\
& + 1.4033\,(S \times D) - 0.5717\,(M \times D) - 0.0154\,(SE^2 \times D^2) \\
& - 0.3544\,(S \times M^2 \times D^2) + 0.4066\,(S \times SE \times D) + 1.1922\,(S^2 \times SE \times D) \\
& + 0.0642\,(S^2 \times SE^2 \times D^2) + 1.9431\,(S \times M^2 \times SE \times D)
\end{aligned}
$$

TOTAL VARIANCE (R^2) = 91.08

STANDARD ERROR OF ESTIMATE = 6.79

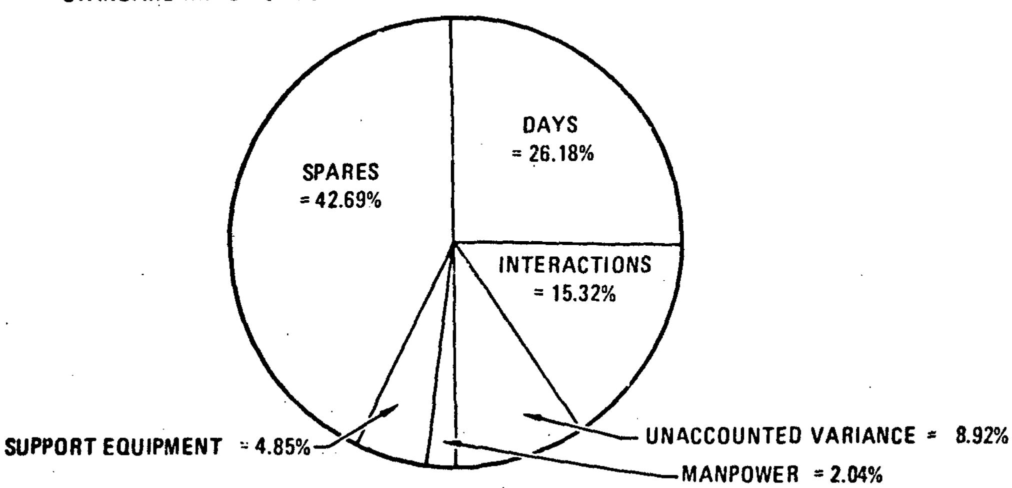

FIGURE 14 DISTRIBUTION OF VARIANCE IN PERCENT SORTIES ACCOMPLISHED DUE TO A REGRESSION MODEL BASED ON MANPOWER, SPARES, SUPPORT EQUIPMENT AND DAYS

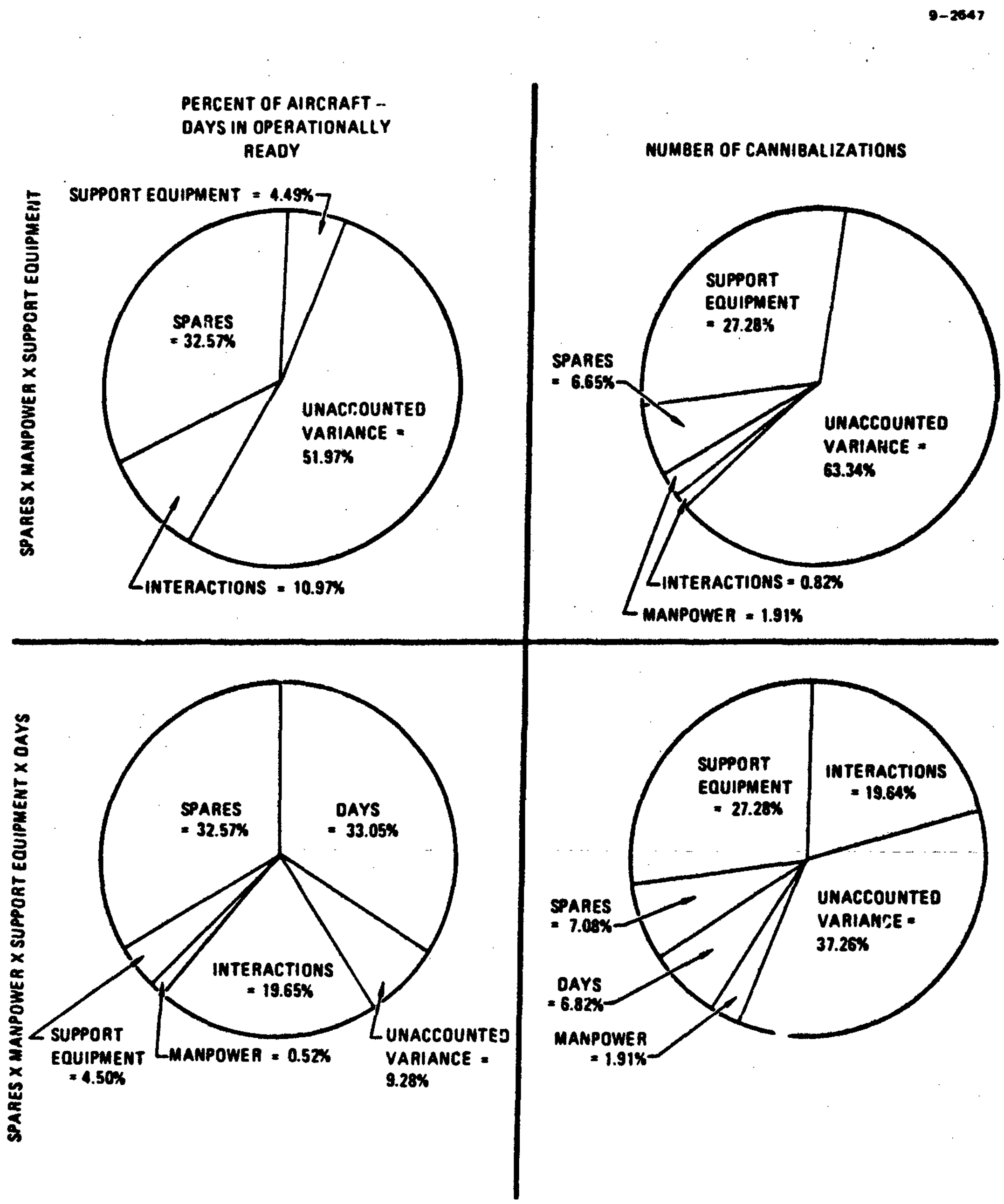

FIGURE 15 EXAMPLES OF VARIANCE DISTRIBUTIONS FOR TWO LCOM VARIABLES ESTIMATED BY TWO REGRESSION MODELS

TABLE 6 TOTAL PERCENTS OF VARIANCE ACCOUNTED BY TWO REGRESSION MODELS

	PERFORMANCE MEASURE	SPARES X MANPOWER X EQUIPMENT	SPARES X MANPOWER X EQUIPMENT X DAYS
	Dependent Variables		
	Operations		
03	Percent accomplished-missions	43.44	91.72
02	Percent accomplished-sorties	51.45	91.08
	Aircraft		
15	Percent on sorites (including alert)	48.24	91.89
16	Percent in unscheduled maintenance	47.87	91.65
17	Percent in schedules maintenance	59.16	84.31
18	Percent in NORS	52.71	95.11
19	Percent in mission wait status	25.97	79.53
20	Percent in service plus waiting	67.76	85.79
21	Percent in operationally ready	48.03	90.28
22	Average aircraft post-sortie time (hour)	21.21	22.66
23	Average number of sorties per aircraft per day	47.04	92.87
24	Flying hours	48.24	91.89
	Manpower		
23	Percent utilization	63.32	92.23
29	Manhours used (x100)	51.69	91.32
30	Percent unscheduled maintenance	8.20	45.31
31	Percent scheduled maintenance	8.20	45.31
33	Number of men demanded	50.03	92.37
34	Percent men available (Prime)	74.55	94.23
38	Percent demands not satisfied	74.47	94.13
40	Simulated maintenance manhours per flying hour	18.88	47.66
	Shop Repair		
44	Number of reparable generations	43.62	86.75
47	Average base repair cycle	43.25	53.13
48	Percent active repair	12.67	12.04
49	Percent white space	6.60	12.35
	Spares Supply		
55	Percent fill rate	60.24	79.79
56	Number of backorder days	60.24	79.79
57	Number of units demanded	50.14	98.97
58	Percent units off-the-shelf	43.07	87.36
61	Percent demands not satisfied	60.24	79.79
62	Number of cannibalizations	36.66	62.74
63	Number of items on backorder	52.98	99.05
	Support Equipment		
71	Equipment percent used - unscheduled maintenance	78.61	90.94
72	Equipment percent used - scheduled maintenance	13.11	19.85
73	Equipment percent unused	78.65	91.12
74	Number of backorder days	50.05	98.98
75	Number of units demanded	43.72	86.09
79	Equipment percent demands not satisfied	62.78	77.78

NOTE: Variables 18-Average aircraft pre-sortie time (hours), 45-Percent base repair, and 46-Percent depot repair were evaluated. However, no predictors met the 0.001 significance level for entry into a model. Consequently, there were no estimating models for these dependent variables.

random changes as a function of very large variations in a resource. The correlation between the resource and the measure in this case would be zero, and therefore, no predictive capability would exist knowing the resource level. In the present study, more extreme quantities of manpower, for example, would have induced larger changes in some LCOM measures and then would have figured more prominently in the predictive models.

A second type of modeling improvement stems from the fact that changes in several LCOM measures were intimately related to changes in other measures. For instance, the first-order correlation between Percent Sorties Accomplished and Percent in NORS exceeded -.95 in the present simulations. Obviously processes which are involved in simulation of an O&M environment affect both measures in opposite directions. Our present regression models treated changes in each performance measure as though they occurred independently of changes in the remaining measures. However, several measures reflect common underlying processes, and more sophisticated prediction models which take these performance measure relationships into account will greatly enhance the modeling effort. Simultaneous models of several interdependent linear equations can be derived after postulating a causal model relating changes in a performance measure to changes in both resources and system performance. Each equation that results from this approach corrects the mutual biases presently contributing to our regression models.

IV. CONCLUSIONS

The present study examined the performance of a 72-aircraft weapon system in a wartime surge environment under a variety of resource conditions. With respect to the study parameters, the major sources of variance in 40 performance measures were attributed to spare parts supplies and day of the surge activity. Increasing the spares supplies available at the beginning of simulation increased the period during which heavy flying demands could be sustained. However, flying activity tended to deteriorate across days, and very rapidly so when resource levels were quickly exhausted on the early days of the surge. Manpower, support equipment, and interactions among the three principal resources enhanced predictive capabilities for most LCOM measures, but accounted for smaller portions of variance than did either spares levels or days.

With respect to the regression models that were developed with simulation results, indications were that a simple model which included predictive components based on Manpower, Spares, and Equipment generally did not provide stable or accurate estimates of system performance. Variance percentages accounted for with this first type of model ranged from 6.60% to 78.65%. Substantial increases in predictive strength were obtained from a model which, in addition to components based on the three resources, included the linear and quadratic Days components. This model predicted from 12.04% to 99.05% of the variance in the 40 performance measures. The increase in predictive strength appears to justify the added complexity of the second model compared to the simpler model without the Days component.

Finally, the second model type yielded very encouraging results concerning the application of simulation and mathematical modeling techniques to the surge environment. However, an aspect of modeling which can be improved is the treatment of interdependencies among performance measures. Simulation results showed strong relationships among many performance measures, relationships which were not a contractual part of this study. Many benefits are realized in moving from the use of stepwise regression techniques to an approach which addresses interrelationships among dependent measures. One approach consists of developing a model of performance change which postulates a causal relationship between the measure of interest, other performance measures and resource quantities. This approach treats the interdependencies among performance measures and provides a statistical solution to biases in our current models.

RECOMMENDATIONS

The present methodology can be applied to a variety of Air Force estimation problems. Our analyses have concentrated on rather global measures of weapon system performance, but there is no reason that equally good predictive devices cannot and should not be derived for finer details in the O&M environment. Performance changes as a function of resource levels should be examined at the AFSC, LRU, and drawer level

among manpower, spares, and equipment, respectively. Estimates of the use of these resources, and their mutual impact on one another can help identify specific resources that may create critical problems. Tradeoffs between resource needs likewise are more easily identified when estimates address specific types of personnel, supplies, and equipment.

The research efforts to date have addressed peacetime and surge scenarios under well-defined resource and environmental conditions. There are many additional conditions which can be examined with simulation and modelling, including:

1. Chemical warfare environment. Protective suits and specialized equipment can reduce the rate at which maintenance tasks are performed. Aircraft turnaround times might be expected to increase in a contaminated environment, and modeling techniques can give advance estimates of the deficits to be expected.

2. Variations in mission scheduling. This research effort considered only a launch window of 14 hours per day and no single aircraft launches.

3. Variations of deployment policies. Our simulations assumed a 72 UE wing at a single base. Other variations would include deployment of separate and self-sustaining operational locations of 48 UE and 24 UE. Furthermore, other wing sizes should be examined, for instance 54 UE, 36 UE, and 18 UE.

4. Variations in organization structure. Structures which include the Combat-Oriented Maintenance Organization (COMO) concept of maintenance manpower need to be explored, and modeling provides a viable technique for rapid appraisal of this concept in many environments.

5. Variations of data base compression. Simulation modeling with a detailed data base can use enormous amounts of static computer storage and involve lengthy run durations which require additional dynamic storage. The purpose of an addition to this research effort was to develop methods for reducing storage and run duration by condensing the detailed data base and to assess whether this results in distortion of system performance estimates, and if so, to what degree. The results (reported in Reference 22) clearly show that significant reductions can be made to a fully detailed LCOM data base, without severely distorting most output measures under unconstrained resource conditions. We argued from the results with six unconstrained simulations that slight differences in output measures could reasonably be attributed to (a) a failure to adjust all variance estimates associated with the lognormal distributions of task durations and (b) discrepancies in the proportion of

failed parts that were routed to the depot. Personnel measures, the only metric that was seriously distorted in unconstrained runs, varied across data base because crew sizes were underestimated after compression. However, even these output discrepancies amounted to only 10% variation from values generated with the five-digit base, and correcting crew sizes by recomputing several three-digit networks is certain to enhance correspondence of personnel measures.

Results from constrained resource runs suggested that memory use was a function of flying activity accomplished and not of flying activity requested. LCOM outputs were distorted in the runs, and unraveling the reasons for the distortions is a tortuous process given the interdependencies among many output measures. It appears, however, that in addition to the problems that were discussed with unconstrained resource runs, manning lay-in quantities were not equivalent across data bases in constrained runs. The combination of all data base differences biased LCOM measures toward superior weapon system performance with the compressed base. In retrospect, a more appropriate procedure for describing personnel and determining quantities of AFSC types would have been to create arbitrary AFSC designations, one per 10 shops, and then man at the shop level. New estimates of manning levels would be required for the compressed base from expected utilization per AFSC per shop if this approach were taken. There is no simple correspondence between five-digit AFSC types and the maintenance shops, which complicates making manpower levels identical across different data bases for purposes of simulation. The manhour problem suggests an LCOM enhancement that would prevent data base discrepancies following network compression. If LCOM were reconfigured to accept noninteger crew sizes, then the Manhours Used measure could be duplicated exactly after any degree of compression.

There is no question that more severe compressions to the two-or one-digit WUC levels would reduce storage and execution costs much further than what has been accomplished here with the three-digit level compression. There is strong evidence that output measures can be controlled to within the fluctuations of random effects in LCOM. The benefits for the investigator include an ability to generate accurate measures of system availability and performance within relatively short time periods and for a fraction of the computer costs of larger simulations, Reference 25.

6. Battle damage assessment and the impact of aircraft attrition on resource requirements. Figure 16 presents preliminary data collected relating Percent Sorties Accomplished to days under four attrition rates for certain mission types. The surge scenario from the present study was used, there were 72 aircraft

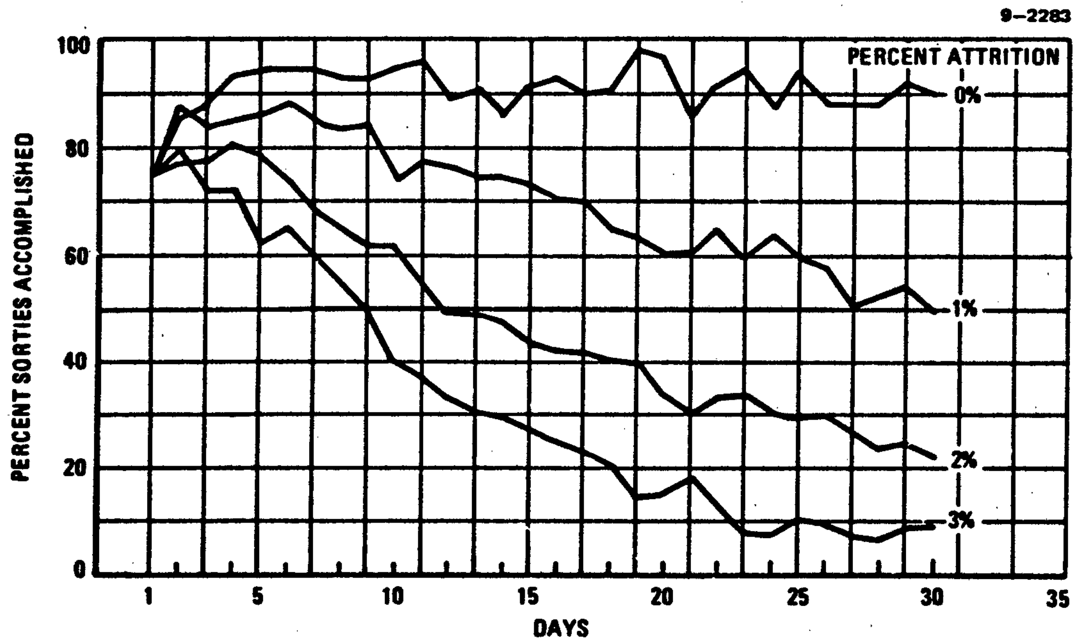

FIGURE 16 EFFECTS OF ATTRITION ON PERCENT SORTIES ACCOMPLISHED OVER 30 DAYS

on Day 1, and resources were unlimited. As can be seen, sorties percents declined rapidly over 30 days with aircraft attrition rates as low as 3%. These estimates are of obvious use for tactical purposes.

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ABBREVIATIONS AND ACRONYMS

AA	Air-to-Air Fighter Sweep
AAR	Air-to-Air Refueling
ACT	Air Combat Tactics
AFHRL	Air Force Human Resources Laboratory
AFIT	Air Force Institute of Technology
AFLC	Air Force Logistics Command
AFM	Air Force Manual
AFMEA	Air Force Management Engineering Agency
AFR	Air Force Regulation
AFSC	Air Force Speciality Code
AFTEC	Air Force Test and Evaluation Center
AFTO	Air Force Technical Order
AIS	Avionics Intermediate Shop
ASD	Aeronautical Systems Division, Air Force Systems Command
BLSS	Base Level Supply System
BMD02R	Biomedical Computer Program
CAP	Combat Air Patrol
CLSS	Combat Logistics Support Squadron
COMO	Combat Oriented Maintenance Organization
CONUS	Continental United States
CTA	Combat Turn-Around
CTD	Combat Turn Director
D	Day
DO	Deputy Chief of Staff, Operations
DoD	Department of Defense

E	Mutually Exclusive Probability
ESC	Escort
FMC	Ful Mission Capable
FY	Fiscal Year
G	Non-mutually Exclusive Probability
GNP	Gross National Product
HQ	Headquarters
IAF	Intercept Alert Force
LCOM	Logisics Composite Model
LG	Logistics
LRU	Line Replaceable Unit
M	Manpower
MAC	Material Air Command
MDS	Mission-design-series
MHE	Maintenance Handling Equipment
MMH/FH	Maintenance Manhours per Flight Hour
MMICS	Maintenance Management Information and Control System
Mod-Metric	Multi-Item, Multi-Echelon, Multi-Indenture Inventory Model
MSBMA	Mean Sorties between maintenance actions
N	Night
NMC	Not Mission Capable
NMCS	Not Mission Capable Supply
NORS	Non-Operationally Ready Rate Supply
O&M	Operations and Maintenance
OR	Operationally Ready
PMC	Partial Mission Capable

PMCB	Partial Mission Capable Both (Maintenance and Supply)
PMCM	Partial Mission Capable Maintenance
PMCS	Partial Mission Capable Supply
POM	Program Operations Memorandum
RAM	Rapid-Area Maintenance
S	Spares
SAC	Strategic Air Command
SAS	Statistical Analysis System
SE	Support Equipment
SECDEF	Secretary of Defense
SNMCB	Scheduled not mission capable both (Maintenance and Supply)
SNMCM	Scheduled not mission capable maintenance
TAC	Tactical Air Command
TFW	Tactical Fighter Wing
UE	Unit Equipped
UNMCB	Unscheduled not mission capable both (Maintenance and Supply)
UNMCM	Unscheduled not mission capable maintenance
UR	Utilization Rate (flying hours per aircraft per month)
USAF	United States Air Force
USAFE	United States Air Force Europe
WRSK	War Readiness Spares Kit
WUC	Work Unit Code

APPENDIX A

COMBAT SORTIE GENERATION MAINTENANCE CONCEPT

This Appendix contains an abbreviated description of the combat sortie generation maintenance concept covered in Reference 20.

Management of maintenance will be subdivided into two distinct efforts; combat turnarounds and repair of aircraft that return non-mission capable. The latter effort can be further divided into fast-and hard-fix categories. The division of work, coupled with the pre-positioning of logistics resources, will allow the regeneration effort to focus on specific tasks and priority locations of the most available aircraft.

In order to enhance aircraft availability, phased, periodic, and calendar inspections, as well as time-compliance (with the exception of life-sustaining items), may be discontinued. Ground crew system checks will be terminated, except when specifically requested by the aircrew, and end-of-runway, last-chance inspections may be suspended. In addition, combat inspection criteria and requirements, identified in appropriate technical data, will take effect.

The manpower available to regenerate aircraft will also be enhanced during combat sortie generation operations. First, cross-utilization of skilled personnel may be employed to insure maximum productivity. Second, direct sortie production functions will be augmented.

Mission-capable aircraft will be combat-turned under the supervision of the combat turn director (CTD). Non-mission-capable aircraft requiring less than 4 hours to repair will be parked in the fast-fix areas and managed by organizational-level personnel. Non-mission-capable aircraft requiring over 4 hours to repair will be parked in the hard-fix areas and managed by job control. Battle-damaged aircraft beyond the repair capability of the unit will be repaired by the Air Force Logistics Command (AFLC) Combat Logistics Support Squadron (CLSS).

The number of aircraft munitions configurations will be kept to a minimum and standardized as much as possible to optimize munitions support. Munitions will be preassembled to the greatest extent possible. At the appropriate alert warning, predetermined loads will be assembled, preloaded as applicable, and delivered to loading or holding areas.

Munitions control function personnel, through the munitions liaison officer (nine-level) in the mission planning cell (frag shop), will monitor the projected need for complete round munitions. Weapons release and gun services personnel will perform only mission-essential requirements during the surge period.

Equipment maintenance personnel will defer or delay 7-day and 180/360-day periodic inspections to reduce maintenance handling equipment

(MHE) downtime. These inspections may be accomplished if the sortie generation rate is not jeopardized. A mobile, quick-fix capability will be developed and maintained to accomplish on-the-road repairs, as well as the repair of other munitions support equipment such as missile and preload support equipment.

The regeneration flow of aircraft begins when the aircrew reports aircraft mission capability status per guidance contained in Reference 20. Returning aircraft will taxi to a cursory check area to confirm mission capability status. The cursory check will be accomplished with engines running, and the aircraft will be directed to the appropriate location for regeneration. Mission-capable aircraft (capable of performing next fragged mission) will be combat-turned by using the applicable, integrated-combat-turnaround procedures. Aircraft, wherein minor maintenance can be accomplished without aircraft power and without interfering with combat-turnaround operations, will also be combat turned. Simultaneous refueling, repair, and munitions loading will be accomplished. Aircraft that break and cannot be repaired in a reasonable time will be immediately relocated.

Non-mission-capable aircraft or aircraft requiring maintenance actions that do not meet the requirements of Reference 20, that return for refueling and immediate launch without weapons reloading, will taxi to the hot refueling area, if applicable. Upon completion of hot refueling, aircraft requiring maintenance will be taxied to fast- or hard-fix recovery locations. Aircraft that are refueled for immediate launch will be taxied out of the hot refueling area to an engine start/arm area for engine restart and removal of ground safety pins.

Each aircraft will be used, to the maximum extent feasible, as a test bench to isolate malfunctions. Under no circumstances during a combat-turn will maintenance requiring access to the cockpit be performed simultaneously with munitions loading.

As out-of-commission aircraft are returned to mission-capable status, Paragraph 2-2e(2) of Reference 23, they will be turned over to the CTD for regeneration by using the appropriate, integrated-combat-turnaround procedures. Self/cartridge starts will be used in the combat turn-arounds (CTAs) when feasible.

Supply points, consisting of repair cycle items determined by the chief of maintenance to be mission-essential and to best accommodate the quick-turn, sortie-surge concept, will be established and located in the maintenance area performing most remove-and-replace maintenance during surge operations. Total base sets to include the war readiness spares kit (WRSK)/base level supply system (BLSS) will be used to fill prepositioning authorizations.

APPENDIX B

AFSC SHIFT ALLOCATIONS

Table B-1 lists the number of personnel, per Air Force Specialty Code (AFSC), assumed available for the present simulations. Quantities are given for each of 38 AFSCs on both 12-hour shifts for the three levels of manpower examined. The three levels sample a wide range of manpower and were selected with the following criteria:

Level	Criteria
1	Manning levels per AFSC assured an average NORS rate of less than 5% for a peacetime utilization rate of 10 sorties per aircraft per month (UR=10). Levels were established after spares quantities had been determined using the same criterion.
2	Manning levels per AFSC assured an average NORS rate of less than 5% for a peacetime UR=20. Levels were established after spares quantities had been determined using the same criterion.
3	Manning levels per AFSC assured an average NORS rate of less than 5% for a peacetime UR=30. Levels were established after spares quantities had been determined using the same criterion.

TABLE B-1 AFSC SHIFT ALLOCATIONS

AFSC	LEVEL 1 SHIFT 1	LEVEL 1 SHIFT 2	LEVEL 2 SHIFT 1	LEVEL 2 SHIFT 2	LEVEL 3 SHIFT 1	LEVEL 3 SHIFT 2
236C1	2	4	2	4	2	4
316L1	9	18	9	18	9	18
324X0	2	2	3	4	5	5
326A0	4	6	6	12	10	12
326A2	18	24	15	30	24	30
326B0	8	6	10	12	18	16
326B2	20	16	28	16	50	40
326C1	8	10	8	10	12	14
326C2	16	10	4	20	10	22
326D1	10	8	8	12	14	10
326E1	6	6	6	6	6	6
326L2	2	4	2	4	2	4
32601	3	6	3	6	3	6
423T3	2	4	2	4	2	4
423X0	10	14	6	18	21	24
423X1	6	12	6	15	12	18
423X2	6	6	3	6	9	9
423X3	9	12	6	15	15	15
423X4	12	15	6	18	21	27
423X5	2	3	4	6	7	10
426T2	4	8	4	8	8	8
426X2	14	28	16	36	44	46
427X0	6	6	3	6	6	9
427X1	2	4	2	4	2	4
427X2	3	6	3	6	3	6
427X3	2	4	2	4	2	4
427X4	2	4	2	4	2	4
427X5	10	15	10	15	20	21
431E1	10	8	18	12	26	26
431P1	15	15	15	15	15	15
431R1	8	8	8	8	12	12
431W1	2	4	2	4	2	4
431X1	54	42	66	60	120	120
461S0	7	14	14	14	14	14
462E0	15	18	27	27	48	48
462G0	9	15	9	21	18	24
462L0	28	20	52	60	118	132
462W0	9	21	15	27	30	39
	355	426	405	567	742	830
	781		972		1572	

APPENDIX C

SPARE PART CONSTRAINTS

This Appendix lists the spare part resources and their four constrained quantities assumed for the present simulations. Parts are listed at the two-digit (Table C-1) and five-digit (Table C-2) WUC levels. Quantities for each digit system represent the sum of all five-digit LRUs within that system. Quantities were entered per line replaceable unit (LRU) for actual runs, however, and the distributions of spare LRUs were proportional according to expected LRU failure rates.

The four levels samples a wide range of spares resources and were selected with the following criteria.

Level	Criteria
1	Total spares quantities yielded an average NORS rate of less than 5% for a peacetime utilization rate of 10 sorties per aircraft per month (UR=10).
2	Total spares quantities yielded an average NORS rate of less than 5% for a peacetime UR=30.
3	Total spares quantities were determined by treating requests for spares as a Poisson process. Sufficient spares were made available so that for UR=90, given an expected number of failures of any LRU over the 30-day simulation period, the probability of having that LRU on hand was .85. Removal rate is a function of UR, and the expected number of removals is a function of shop and depot repair probabilities, shop and depot resupply cycle time, and simulation period. Appendix D gives a detailed description of this approach to estimating spares quantities.
4	Total spares quantities yielded a daily sortie rate that was not significantly different from the daily rate achieved when spare quantities were unlimited. Three simulations with unlimited resources established a "sortie rate band" which averaged approximately 92% per day for a UR=135 requested sortie rate. The largest spares quantity examined in the present study insured that sortie rate remained within or near the extremes of this band on each simulated day of flying.

TABLE C-1 SYSTEM SUMMARY OF SPARE PART CONSTRAINTS

WORK UNIT CODE	DESCRIPTION	LEVEL: 1	2	3	4
			NUMBER OF SPARES		
11	Airframe	29	32	37	40
12	Cockpit and Fuselage Compartments	12	18	55	64
13	Landing Gear System	30	45	108	122
14	Flight Controls	32	42	59	70
23	Power Plant	79	155	350	126
24	Secondary Power System	27	43	61	76
41	Enviornmental Control System	22	32	55	68
42	Electrical System	11	20	32	39
44	Lighting System	21	25	24	26
45	Hydraulic System	19	23	24	26
46	Fuel System	28	38	64	74
47	Oxygen System	8	16	30	35
49	Miscellaneous Utilities	6	7	12	14
51	Instruments	20	29	63	83
52	Autopilot and Recording Equipment	5	7	7	8
55	Malfunction Analysis and Flight Control System	5	7	11	15
57	Integrated Guidance	1	1	2	3
63	UHF Communications	11	22	25	31
65	IFF System	7	19	18	22
71	Radio Navigation	22	36	42	54
74	Fire Control System	25	60	68	87
75	Weapons Delivery System	25	30	22	27
76	Tactical Warfare Electronic System	18	21	19	21
	TOTALS	463	728	1188	1431

TABLE C-2 SPARE CONSTRAINTS PER LRU

UNIT WORK CODE	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4
11ABO	1	1	1	1
11AFO	1	1	1	1
11AHP	1	1	1	1
11AJA	1	1	1	1
11A99	1	1	1	1
11DJQ	1	1	1	1
11DGT	1	1	1	1
11DHT	1	1	1	1
11DJJ	1	1	1	1
11DJK	1	1	1	1
11DJU	1	1	1	1
11DJV	1	1	1	1
11DJW	1	1	1	1
11DJ4	1	1	1	1
11D99	1	1	1	1
11GRE	1	1	1	1
11GRG	1	1	1	1
11GSL	1	1	1	1
11GSE	1	2	1	1
11GSH	1	1	1	1
11GRX	1	1	1	1
11GSJ	1	1	1	1
11GSW	1	1	1	1
11GS6	1	2	1	1
11PAJ	1	1	1	1
11PAL	1	1	1	1
11PA6	1	1	1	1
11PDO	1	2	3	4
11P99	1	1	1	1
12ABB	3	7	46	55
12CAB	1	1	1	1
12CBA	1	2	1	1
12CBG	1	2	1	1
12CBP	1	1	1	1
12CBQ	1	1	1	1
12CBS	1	1	1	1
12CDB	1	1	1	1
12CFA	1	1	1	1
12CFC	1	1	1	1
13AGA	1	1	1	1
13AGF	1	2	3	4
13AJB	1	1	1	1
13A5A	1	1	1	1
13AJA	1	2	1	2
13ABO	1	1	1	1
13BOO	1	1	1	1
13BAO	1	1	1	1
13BDE	1	2	1	1
13BDP	1	1	1	1
13BEB	2	2	8	10
13BEC	1	2	6	8
13BEI	1	1	1	1
13BGD	1	1	1	1
13BJA	3	12	45	54
13BJB	1	2	4	6
13BJO	1	1	1	1
13CAA	1	1	1	1

TABLE C-2 SPARE CONSTRAINTS PER LRU (CONTINUED)

13CFA	1	1	1	1
13CFB	1	1	1	1
13D00	1	1	1	1
13DB0	2	3	18	14
13DBC	1	1	1	1
13FBD	1	2	5	6
13FB0	1	1	1	1
13HA0	1	1	1	1
14A00	1	1	1	1
14AA0	1	1	1	1
14AAA	1	2	2	2
14ABA	1	2	3	4
14ABB	1	2	3	4
14ABC	1	1	1	1
14ABD	1	1	1	1
14ABJ	1	1	1	1
14ACH	1	1	2	2
14ACA	1	1	1	1
14ACE	1	1	1	1
14AFB	1	2	2	2
14AFD	1	1	1	1
14AFF	1	1	1	1
14CDA	2	3	11	13
14CA0	1	1	1	1
14DA0	1	3	1	1
14DBA	1	1	1	2
14DB0	1	1	1	1
14DBK	1	1	1	1
14DDA	1	1	3	4
14E00	1	1	1	1
14EB0	1	1	1	1
14EBA	1	2	5	6
14EBC	1	2	3	4
14EBG	1	1	1	1
14GB0	1	1	1	1
14GCC	1	2	3	5
14HA0	1	2	3	5
14H00	1	2	3	5
14HBK	1	1	2	3
23000	2	6	3	5
23A00	1	2	1	1
23AA0	1	1	2	2
23AD0	1	2	3	5
23A*0	1	2	1	1
23B00	1	2	1	2
23BL0	1	1	1	2
23BM0	1	2	1	1
23BN0	1	2	3	5
23BP0	1	1	2	2
23B*0	1	2	3	5
23C00	1	2	3	5
23CC0	1	2	3	5
23C*0	1	2	3	5
23G00	1	2	3	5
23GB0	1	1	1	2
23GC0	1	1	1	1
23G*0	1	1	1	1
23HA0	2	3	11	15
23JA0	1	1	4	5

TABLE C-2 SPARE CONSTRAINTS PER LRU (CONTINUED)

23KA0	1	1	1	1
23PA0	1	1	1	1
23B90	1	1	1	1
23QA0	1	1	1	1
23QB0	1	1	1	1
23Q90	1	1	1	1
231AA	1	2	4	5
231AB	1	2	3	4
231AC	1	1	1	1
231AM	1	2	1	1
231D0	1	1	3	1
23FA0	1	1	1	1
23F*0	1	1	1	1
23FB0	1	1	2	2
23B90	1	1	1	1
23AAP	1	1	2	2
23F00	4	10	1	1
23FBC	1	1	2	2
23FAV	1	1	1	1
23FBD	6	40	130	157
23FBE	1	1	1	2
23FBG	1	1	7	9
23HAB	1	3	8	11
23HAD	2	2	7	8
23HAG	1	1	1	1
23HAM	1	1	1	1
23HAH	1	2	2	2
23HAN	1	1	1	1
23HAQ	1	1	1	1
23JAA	1	1	1	1
23JAC	1	1	1	1
23JAJ	1	1	1	1
23KAG	1	1	1	1
23KAH	1	2	4	6
23KAJ	1	1	1	1
23KAR	1	2	3	5
23PAB	1	2	2	3
23PAN	1	1	1	1
23PAK	1	2	1	1
23PAL	1	1	1	1
23PAC	1	2	1	2
23QA4	3	4	101	125
23QAH	1	1	1	1
23QAN	1	1	1	1
231AG	1	1	1	4
231AB	1	1	1	1
24AD0	1	2	1	2
24ADM	1	2	4	5
24ADA	1	1	1	1
24ADW	1	1	1	1
24ANU	1	1	1	1
24AD7	1	1	1	1
24AN0	2	4	10	14
24ANA	1	2	2	3
24ANG	1	1	1	1
24ANH	1	1	1	1
24ANM	1	2	1	1
24B00	1	2	1	1
24BA0	1	1	6	8
24BAC	1	2	3	4
24BAD	1	1	1	1
24B80	1	3	7	9

TABLE C-2 SPARE CONSTRAINTS PER LRU (CONTINUED)

24BBS	1	3	1	1
24BBB	1	2	1	1
24BDO	1	2	6	8
24BBH	1	2	1	2
24BBL	1	3	1	1
24BDA	1	3	1	1
24DAA	1	3	1	1
24DAB	1	2	5	6
24DAD	1	3	1	1
24DAG	1	3	1	1
41AAC	1	3	1	1
41AAJ	1	2	1	1
41AAL	1	1	1	2
41AAR	1	2	4	5
41AAS	1	1	2	2
41ABY	1	3	1	1
41ABG	2	3	8	10
41ABL	1	3	1	1
41ABP	1	2	6	8
41ABQ	1	2	4	5
41ABS	1	3	1	1
41ABX	1	3	1	1
41ACF	1	2	2	3
41ACM	1	1	2	3
41ACZ	1	3	1	1
41AEB	1	2	4	5
41AED	1	2	7	9
41AEE	1	1	2	2
41AEH	1	3	1	1
41CAA	1	2	2	2
41CCA	1	2	3	4
42ADA	1	3	7	9
42ADB	1	2	7	9
42AFO	1	1	1	2
42ARA	1	2	1	1
42CXX	1	2	1	1
42DOO	1	3	1	1
42DBO	1	2	3	3
42FEO	1	1	2	2
42FEB	1	3	5	6
42FEA	1	2	3	4
42FFO	1	2	1	1
44AOO	1	3	1	1
44AAA	1	2	1	1
44AAC	1	3	1	1
44AAD	1	3	1	1
44AAF	1	3	1	1
44AA1	1	2	4	6
44AAN	1	3	1	1
44AAY	1	3	1	1
44AAG	1	3	1	1
44AA3	1	3	1	1
44AAE	1	3	1	1
44AAS	1	3	1	1
44AAZ	1	3	1	1
44A99	1	3	1	1

TABLE C-2 SPARE CONSTRAINTS PER LRU (CONTINUED)

44BAA	1	3	1	1
44BAR	1	3	1	1
44BAV	1	3	1	1
44BFO	1	3	1	1
44EOO	1	3	1	1
44EAO	1	3	1	1
44ECO	1	3	1	1
45AAC	1	1	1	1
45AAR	1	1	1	1
45ABO	1	1	1	1
45ABD	1	2	1	1
45ABJ	1	1	1	1
45ADO	1	2	1	1
45BAE	1	1	1	1
45BBJ	1	1	1	1
45BBA	1	1	1	1
45BBD	1	1	1	1
45BFO	1	1	1	1
45CAC	2	3	5	6
45CBO	1	1	1	1
45CDC	1	1	1	1
45CDA	1	1	1	1
45CDE	1	1	1	1
45CDH	1	2	1	1
45CFO	1	1	3	4
46AAA	1	2	4	6
46AAW	1	1	1	1
46ABA	1	1	1	1
46ACG	1	1	1	1
46ACA	1	1	1	1
46ADE	1	4	11	14
46ADG	1	1	1	1
46ADR	1	1	1	2
46ADS	1	2	2	2
46ADU	1	1	2	1
46AEJ	1	1	1	1
46BAA	1	1	1	1
46BCC	1	2	2	2
46BCH	1	2	4	6
46DOO	1	1	1	1
46DAD	1	1	1	1
46DAF	1	1	1	1
46DBE	1	1	1	1
46EOO	1	1	1	1
46EAB	1	1	1	1
46EBA	1	1	4	5
46EBF	1	1	1	1
46EBJ	1	1	1	1
46EBH	1	1	1	1
46ECD	1	1	1	1
46EDA	1	2	5	6
46EDB	1	3	11	14
46EEE	1	1	1	1

TABLE C-2 SPARE CONSTRAINTS PER LRU (CONTINUED)

47AAC	1	1	1	1
47AAE	1	2	2	3
47AAH	2	5	16	18
47AAK	1	1	1	1
47AAL	1	4	4	5
47AAS	1	1	1	1
47AAX	1	2	5	6
49AAC	1	1	2	2
49AAL	1	1	1	1
49ABA	1	1	1	1
49ABB	1	1	1	1
49AAP	1	2	6	8
49AAM	1	1	1	1
51AA0	1	1	1	1
51AD0	2	3	11	15
51AE0	1	1	3	4
51AF0	1	2	8	11
51AG0	1	1	1	1
51AH0	1	2	5	7
51AJ0	1	1	3	4
51AK0	1	2	3	5
51AM0	1	2	5	6
51EA0	1	1	1	2
51EAA	1	1	1	1
51ED0	1	2	4	5
51EE0	1	1	1	1
51EEA	1	1	1	1
51MA0	1	1	1	1
51MB0	1	1	1	1
51NA0	2	4	7	9
51NB0	1	2	6	8
52AA0	1	2	2	3
52AB0	1	1	1	1
52AC0	1	1	1	1
52AL0	1	2	2	2
52AH0	1	1	1	1
55AC0	1	1	1	1
55AE0	1	2	2	3
55AD0	1	1	1	1
55BC0	1	2	6	9
55CA0	1	1	1	1
57AA0	1	1	2	3
63AA0	1	3	2	3
63AC0	1	1	1	1
63AC0	1	1	1	1
63AG0	1	2	1	2
63AN0	1	1	1	1
63AM0	1	1	1	1
63BC0	1	2	7	9
63BD0	1	2	1	1

TABLE C-2 SPARE CONSTRAINTS PER LRU (CONTINUED)

63BE0	1	1	1	1
63BF0	1	1	1	1
63GH0	1	7	8	10
65AA0	1	3	4	5
65AD0	1	1	1	1
65AB0	1	3	1	1
65BA0	1	4	5	8
65BB0	1	4	1	1
65BH0	1	2	5	5
56B00	1	2	1	1
71AE0	2	4	16	20
71AK0	1	2	5	8
71AKT	1	1	1	1
71AD0	1	1	1	1
71CA0	11	12	2	3
71DA0	1	7	3	4
71DB0	1	1	1	1
71FA0	1	1	1	2
71FB0	1	4	10	12
71FC0	1	2	1	1
71FE0	1	1	1	1
74EB0	1	2	2	2
74FA0	1	6	1	1
74FC0	3	2	10	13
74FJ0	1	2	1	1
74FU0	1	6	1	1
74FF0	1	4	6	8
74F00	1	9	5	6
74FS0	1	5	7	10
74FH0	1	3	2	3
74F00	1	1	2	2
74FG0	1	1	1	1
74FQc	1	1	1	1
74FV0	1	1	1	1
74F99	1	1	1	1
74JA0	2	3	13	18
74JC0	1	2	3	4
74KC0	1	2	2	2
74KA0	2	3	6	9
74KE0	1	4	1	1
74K99	1	1	1	1
74KAP	1	1	1	1
75BB0	11	10	2	2
75BC0	1	4	2	3
75BF0	1	3	2	3
75DA0	1	1	1	1
75FA0	1	1	1	1
75MA0	2	1	3	4
75MC0	1	2	4	6
75HDM	1	1	1	1
75HDE	1	1	1	1
75HE0	1	1	1	1

TABLE C-2 SPARE CONSTRAINTS PER LRU (CONCLUDED)

75NAB	1	1	1	1
75NAE	1	1	1	1
75NAD	1	1	1	1
75NAC	1	1	1	1
75AA0	1	2	1	2
76AC0	1	2	1	2
76AF0	1	1	1	1
76AG0	1	1	1	1
76CA0	1	2	2	2
76GD0	1	1	1	1
76GB0	1	1	1	1
76GE0	1	1	1	1
76GN0	1	1	1	1
76GP0	1	1	1	1
76GF0	1	1	1	1
76HA0	1	1	1	1
76HB0	1	1	1	1
76HF0	1	1	1	1
76HG0	1	1	1	1
76HC0	1	1	1	1
76HLA	1	1	1	1
76HH0	1	1	1	1

APPENDIX D

POISSON PROBABILITY FUNCTION FOR COMPUTING SPARES REQUIREMENTS

This Appendix describes the mathematical procedures for computing spares lay-in quantities assuming failure probabilities per LRU, flying activity, and repair cycle time.

The general equation for the Poisson Probability Function is shown below:

$$P_{(x)} = \frac{e^{-\lambda}\lambda^{x}}{x}$$

where: $P_{(x)}$ = protection level probability value
e = a constant with a value of 2.7183
x = number of spares
λ = expected number of removals over the simulation time period

$$\lambda = [P_{DEPOT}(\frac{t_1}{T}) + P_{SHOP}(\frac{t_2}{T})]\ [R]$$

P_{DEPOT} = probability of depot repair
P_{SHOP} = probability of shop repair, $1-P_{DEPOT}$
T = simulation time period
t_1 = depot repair cycle time
t_2 = shop repair/resupply cycle time
R = removal rate = removals/T

P_{DEPOT} and P_{SHOP} are dependent on the types of spare and their corresponding repair cycle times. There are occasions, such as wartime initial-surge, where resupply of spares may not exist. This condition could be represented by a depot repair/resupply cycle time (t_1) equal to the length of the surge time interval.

A FORTRAN computer program has been developed that combines the given Poisson equation with a data base that contains all of the necessary input variables. This data base describes approximately 411 F-15 Line Replaceable Units (LRUs). Because this data base also includes cost data, once the quantities of spares are determined, the total investment cost can also be assessed.

An example of the input information in the data base is shown in Table D-1. An explanation of the input variables is shown in the following equation:

$$\text{LRU Failure Rate} = F_{LRU} = \frac{F}{P_1 \times P_2 \times P_3 \times P_4 \times P_5}$$

TABLE D–1 SAMPLE INPUT DATA FOR DETERMINING SPARE REQUIREMENTS

PROBABILITIES 9–2284

WUC	COST	F	P_1	P_2	P_3	P_4	P_5	P_{DEPOT}
11AB0	15170	0034	0.200	0.021	1.000	1.000	0.000	0.000
11AF0	9900	0034	0.500	0.021	1.000	1.000	1.000	0.000
11AHP	100	0034	0.100	0.021	1.000	1.000	1.000	0.000
11AJA	1430	0034	0.100	0.021	1.000	1.000	1.000	0.000
11A99	100	0034	0.100	0.021	1.000	1.000	1.000	0.000
11DJQ	770	0018	0.169	0.015	1.000	1.000	1.000	0.000
11DGT	280	0018	0.083	0.015	1.000	1.000	1.000	0.000
11DHT	776	0018	0.083	0.015	1.000	1.000	1.000	0.000
11DJJ	199	0018	0.083	0.015	1.000	1.000	1.000	0.000
11DJK	244	0018	0.083	0.015	1.000	1.000	1.000	0.000
11DJU	2358	0018	0.167	0.015	1.000	1.000	1.000	0.000
11DJV	2527	0018	0.083	0.015	1.000	1.000	1.000	0.000
11DJW	1682	0018	0.083	0.015	1.000	1.000	1.000	0.000
11DJ4	380	0018	0.083	0.015	1.000	1.000	1.000	0.000
11D99	100	0018	0.083	0.015	1.000	1.000	1.000	0.000
11GRE	18066	0016	0.167	0.073	1.000	1.000	1.000	0.000
11GRG	697	0016	0.083	0.073	1.000	1.000	1.000	0.000
11GSC	3200	0016	0.168	0.073	1.000	1.000	1.000	0.000
11GSE	360	0016	0.167	0.073	1.000	1.000	1.000	0.000
11GSH	3168	0016	0.083	0.073	1.000	1.000	1.000	0.000
11GRX	10309	0016	0.083	0.073	1.000	1.000	1.000	0.000
11GSJ	5987	0016	0.083	0.073	1.000	1.000	1.000	0.000
11GSW	4456	0016	0.083	0.073	1.000	1.000	1.000	0.000
11GS6	305	0016	0.083	0.073	1.000	1.000	1.000	0.000
11PAJ	13696	0062	0.167	0.369	1.000	1.000	1.000	1.000
11PAL	760	0062	0.033	0.369	1.000	1.000	1.000	0.000
11PA6	760	0062	0.033	0.369	1.000	1.000	1.000	0.000
11PD0	15034	0062	0.766	0.369	1.000	1.000	1.000	0.077
11P99	100	0062	0.001	0.369	1.000	1.000	1.000	0.000
12ABB	1214	0064	0.520	1.000	1.000	1.000	1.000	1.000
12CAB	100	0096	0.063	0.013	1.000	1.000	1.000	0.000
12CBA	1105	0096	0.125	0.013	1.000	1.000	1.000	0.000
12CBB	1247	0096	0.125	0.013	1.000	1.000	1.000	1.000
12CBP	1247	0096	0.125	0.013	1.000	1.000	1.000	0.000
12CCQ	398	0096	0.125	0.013	1.000	1.000	1.000	0.000
12CBS	1227	0096	0.063	0.013	1.000	1.000	1.000	0.000
12CDB	64	0096	0.126	0.013	1.000	1.000	1.000	0.000
12CFA	248	0096	0.188	0.013	1.000	1.000	1.000	0.000
12CFC	100	0096	0.060	0.013	1.000	1.000	1.000	0.000

where: LRU = Line Replaceable Unit

F = 3-digit Work Unit Code (WUC) failure rate (expressed in sorties between maintenance action)

P_1 - P_5 = probability of LRU failure and subsequent removal

An example of the output results is shown in Table D-2. In this example, Time 1 and Time 2 were constants. The removals (R) that are shown were calculated by the following equation:

$$R = \frac{\text{No. of Sorties/Month}}{F_{LRU}}$$

First, a protection level is selected, and then a flying schedule is defined. Generally, the protection level will yield a specific value of Non-Operationally Ready due to Supply (NORS). To satisfy a pre-established NORS criterion (e.g., 5%), it may be necessary to generate spares for several protections levels and then use simulation data to determine their impact on the NORS rate. This will produce helpful sensitivity relationships among spares, NORS, and other related output statistics. The important point is that the given methodology generates spares in a systematic manner.

TABLE D–2 SAMPLE OUTPUT DATA – SPARES LAY-IN REQUIREMENTS

9 2285

PROTECTION LEVEL = 0.85
TIME 1 35.0000
TIME 2 .1667
NUMBER OF SORTIES 4208

WUC	REMOVALS	LAMBDA	SPARES	COST	
11AB0	.520	.003	1	15170	ONE ASSUMED
11AFO	1.300	.007	1	9900	ONE ASSUMED
11AHP	.260	.001	1	100	ONE ASSUMED
11AJA	.260	.001	1	1430	ONE ASSUMED
11A99	.260	.001	1	100	ONE ASSUMED
11DJQ	.593	.003	1	770	ONE ASSUMED
11DGT	.291	.002	1	280	ONE ASSUMED
11DHT	.291	.002	1	776	ONE ASSUMED
11DJJ	.291	.002	1	199	ONE ASSUMED
11DJK	.291	.002	1	244	ONE ASSUMED
11DJU	.586	.003	1	2358	ONE ASSUMED
11DJV	.291	.002	1	2527	ONE ASSUMED
11DJW	.291	.002	1	1682	ONE ASSUMED
11DJ4	.291	.002	1	380	ONE ASSUMED
11D99	.291	.002	1	100	ONE ASSUMED
11GRE	3.206	.018	1	18066	ONE ASSUMED
11GRG	1.594	.009	1	697	ONE ASSUMED
11GSC	3.225	.018	1	3200	ONE ASSUMED
11GSE	3.206	.018	1	360	ONE ASSUMED
11GSH	1.594	.009	1	3168	ONE ASSUMED
11GRX	1.594	.009	1	10309	ONE ASSUMED
11GSJ	1.594	.009	1	5987	ONE ASSUMED
11GSW	1.594	.009	1	4456	ONE ASSUMED
11GS6	1.594	.009	1	305	ONE ASSUMED
11PAJ	4.182	4.879	7	95872	
11PAL	.826	.005	1	760	ONE ASSUMED
11PA6	.826	.005	1	760	ONE ASSUMED
11PD0	19.184	1.822	3	45102	
11P99	.025	.000	1	100	ONE ASSUMED
12ABB	34.190	39.888	46	55844	
12CAB	.036	.000	1	100	ONE ASSUMED
12CBA	.071	.000	1	1105	ONE ASSUMED
12CBB	.071	.083	1	1247	ONE ASSUMED
12CBP	.071	.000	1	1247	ONE ASSUMED
12CBQ	.071	.000	1	398	ONE ASSUMED
12CBS	.036	.000	1	1227	ONE ASSUMED
12CDR	.072	.000	1	64	ONE ASSUMED
12CFA	.107	.001	1	248	ONE ASSUMED
12CFC	.034	.000	1	100	ONE ASSUMED

APPENDIX E

ADDITIONAL SIMULATION DATA ON SELECTED LCOM MEASURES

This Appendix presents plots of seven performance measures. In each plot, there are three panels, one panel per AIS condition. The values for the performance measures are shown on the vertical or y-axis, while the values for the spares are designated on the horizontal or x-axis. Within each panel, the three graphed lines represent three different levels of manpower. Each of the 36 data points represents a 30-day average for one simulation.

To examine the effects of AIS, scan across the panels and judge whether the plotted lines differ in form. Using Figure E-1, as an example, only the AIS=0 panel differs somewhat from the other two panels.

For manpower, examine the spread between plotted lines. The greater the spread between lines, the greater the variation due to manpower. The spread in Figure E-1 is considered moderate.

For spares, examine the slopes of the lines. The steeper the slope, the greater the variation due to spares.

To examine interaction effects, view all plotted lines and assess degree of non-parallelism and convergence or crossover. These are signs of interaction. The obvious crossovers are in panels 1 and 3. If the panels were superimposed, other interactions could be seen.

This visual diagnosis revealed that spares was the dominant factor, and manpower, support equipment, and interactions lesser factors, in contributing to variations in the performance measure.

The mathematical results, Appendices F and G, corroborate the accuracy of the visual diagnosis. For Variable 57, Number of Units Demanded-Spares Supply, 35.81% of the variation in this measure was attributed to spares, 2.95% to manpower, 2.15% to support equipment, and 2.16% to interaction.

The remaining plots can be interpreted in the same manner.

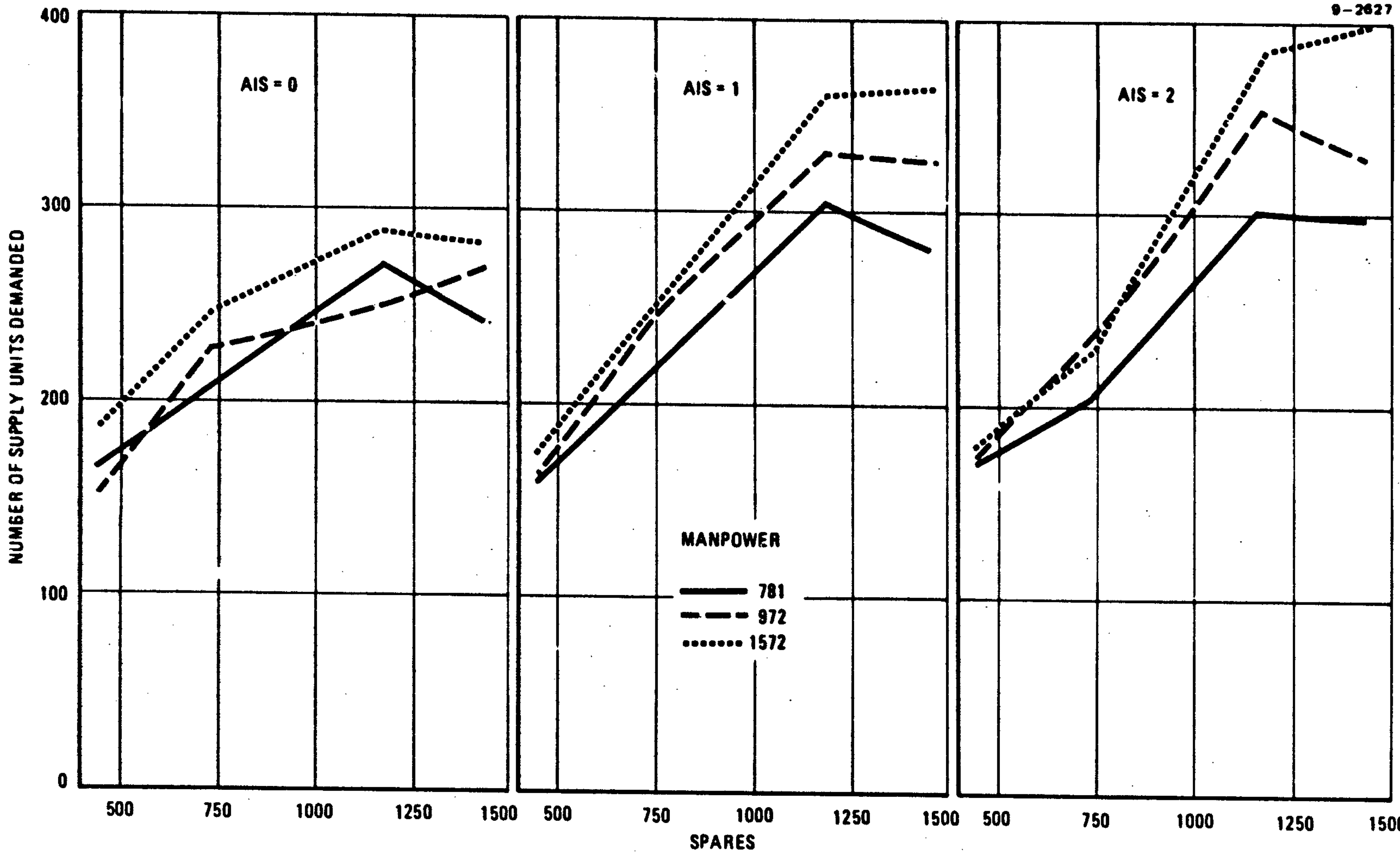

FIGURE E-1 NUMBER OF SUPPLY UNITS DEMANDED AVERAGED OVER 30 DAYS FOR ALL RESOURCE CONDITIONS

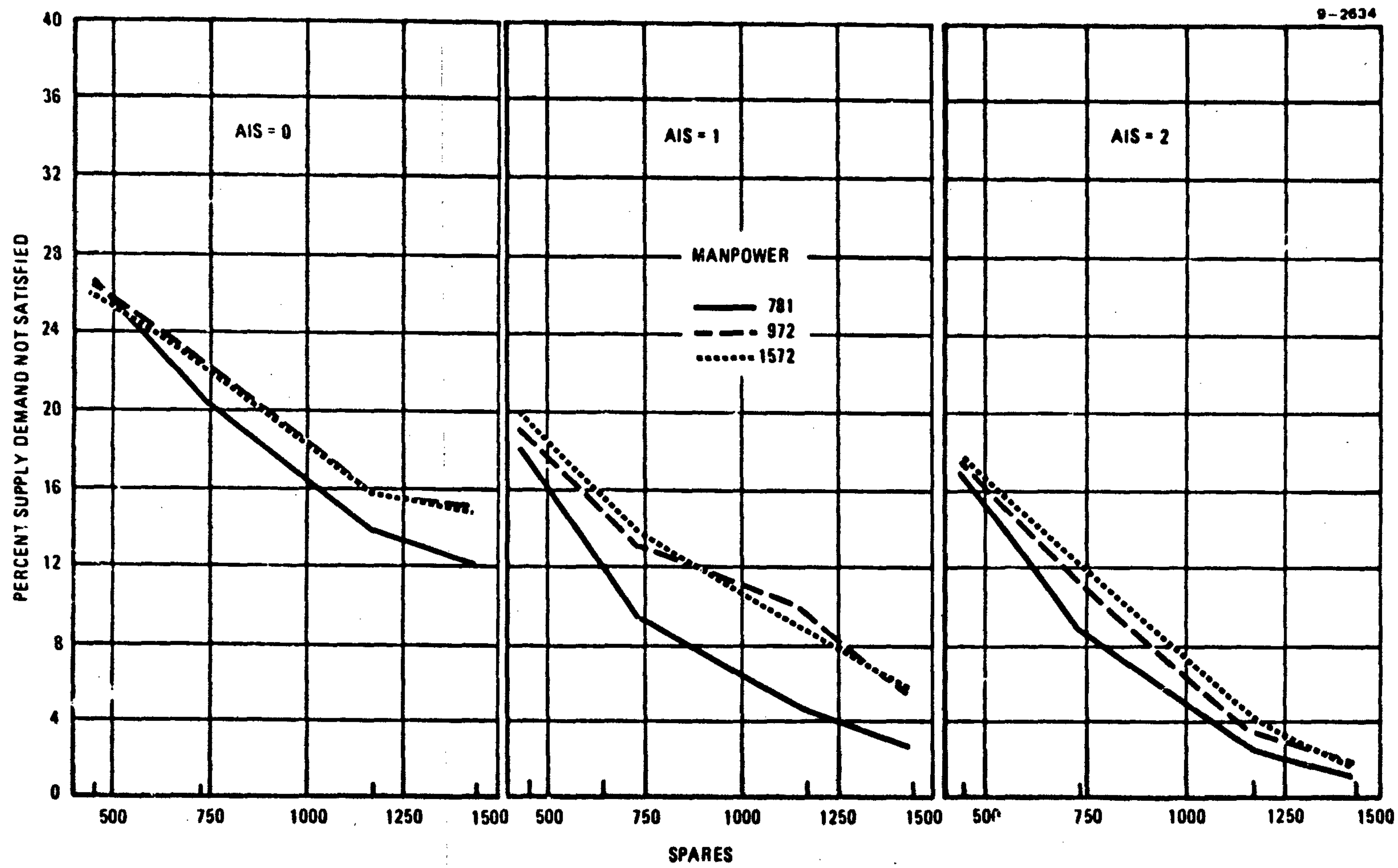

FIGURE E-2 PERCENT SUPPLY DEMAND NOT SATISFIED AVERAGED OVER 30 DAYS FOR ALL RESOURCE CONDITIONS

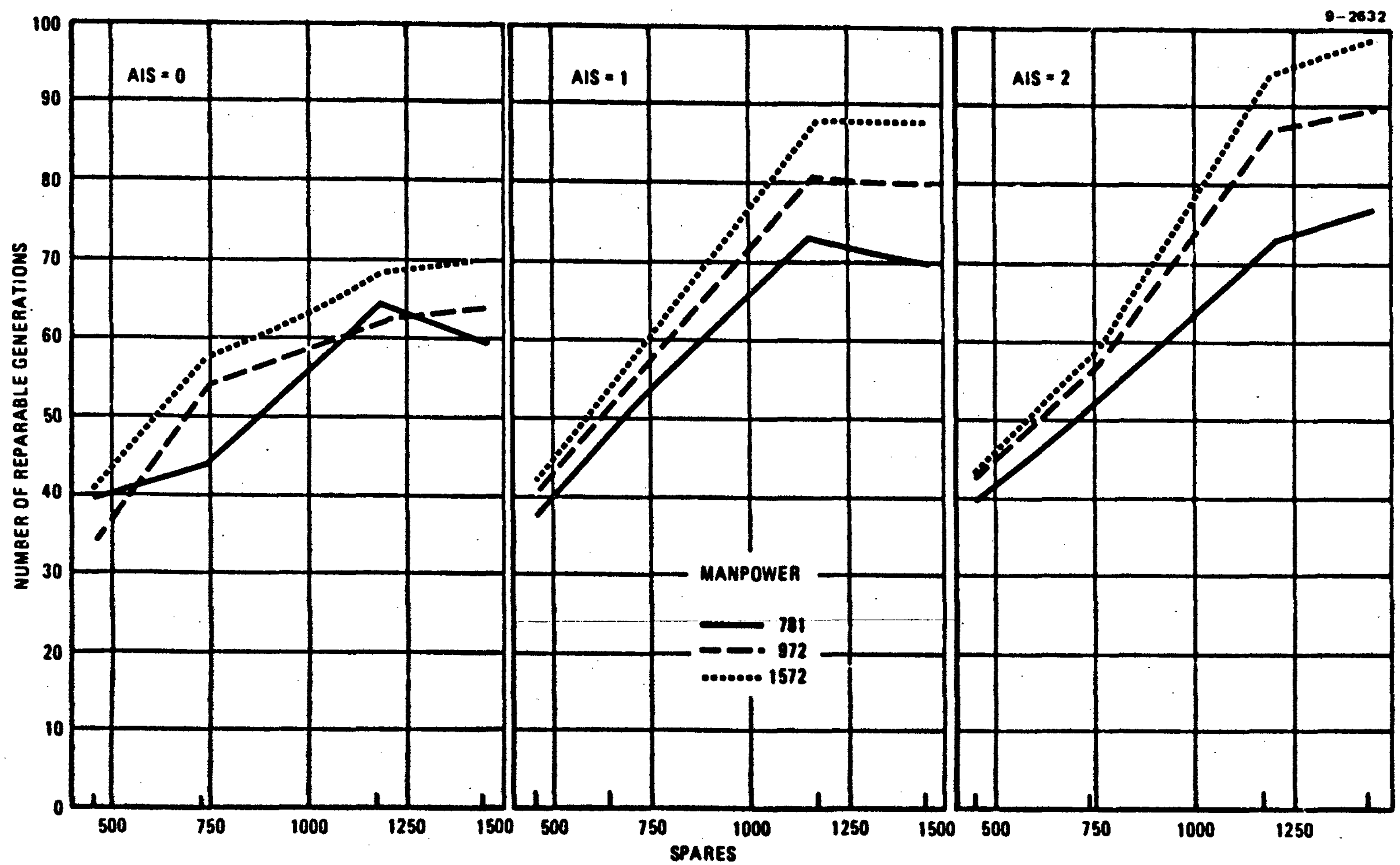

FIGURE E–3 NUMBER OF REPARABLE GENERATIONS AVERAGED OVER 30 DAYS FOR ALL RESOURCE CONDITIONS

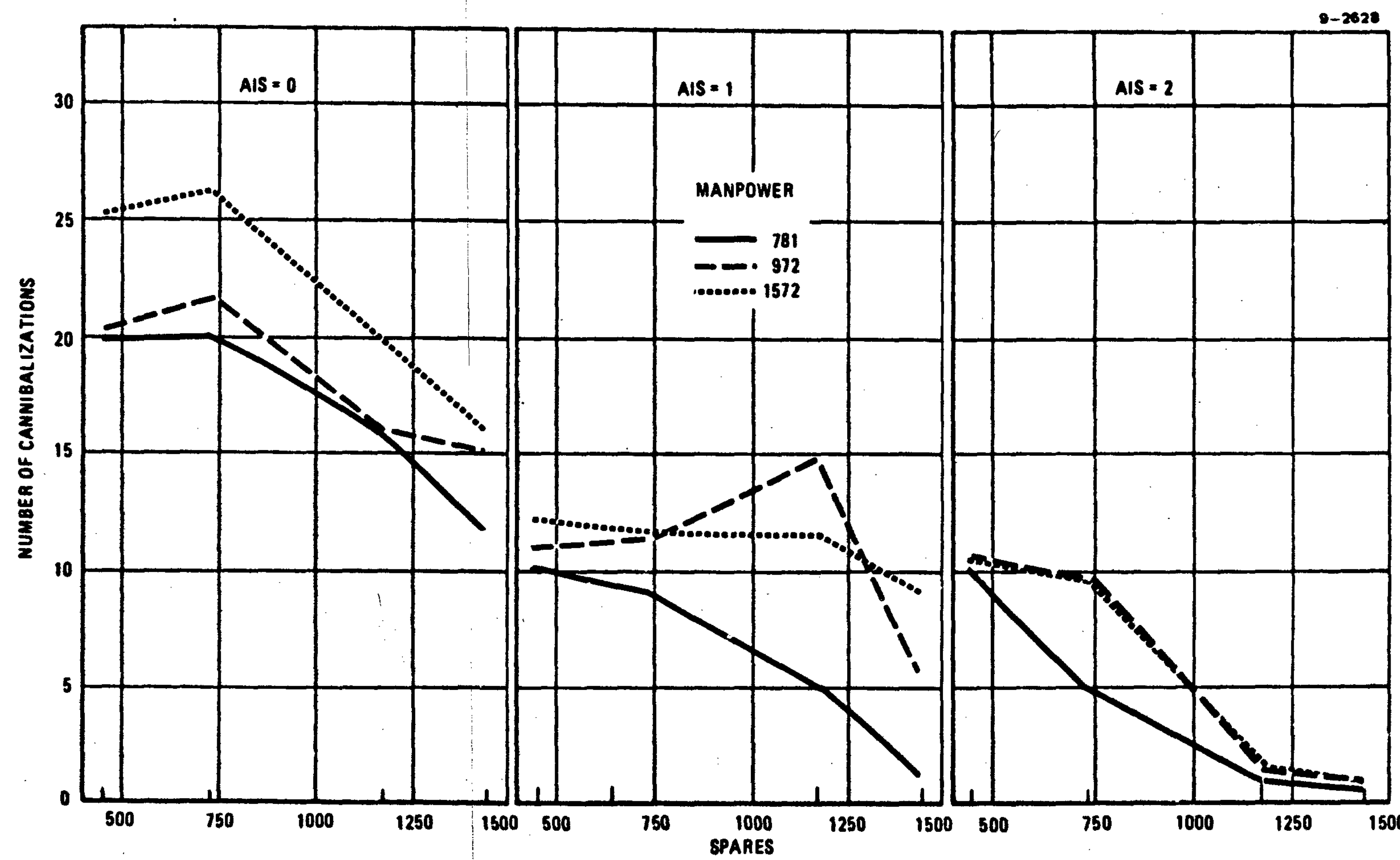

FIGURE E–4 NUMBER OF CANNIBALIZATIONS AVERAGED OVER 30 DAYS FOR ALL RESOURCE CONDITIONS

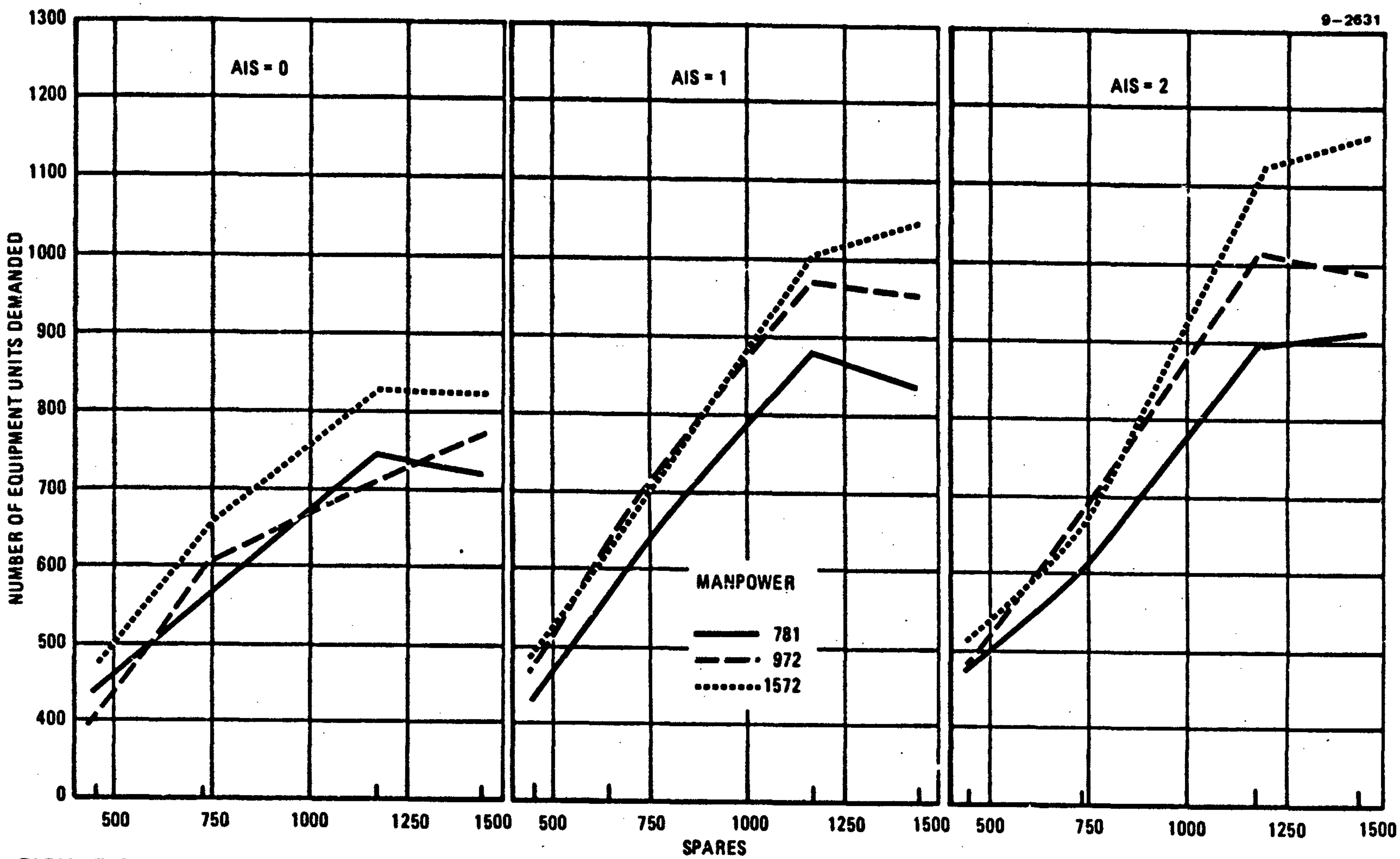

FIGURE E–5 NUMBER OF EQUIPMENT UNITS DEMANDED AVERAGED OVER 30 DAYS FOR ALL RESOURCE CONDITIONS

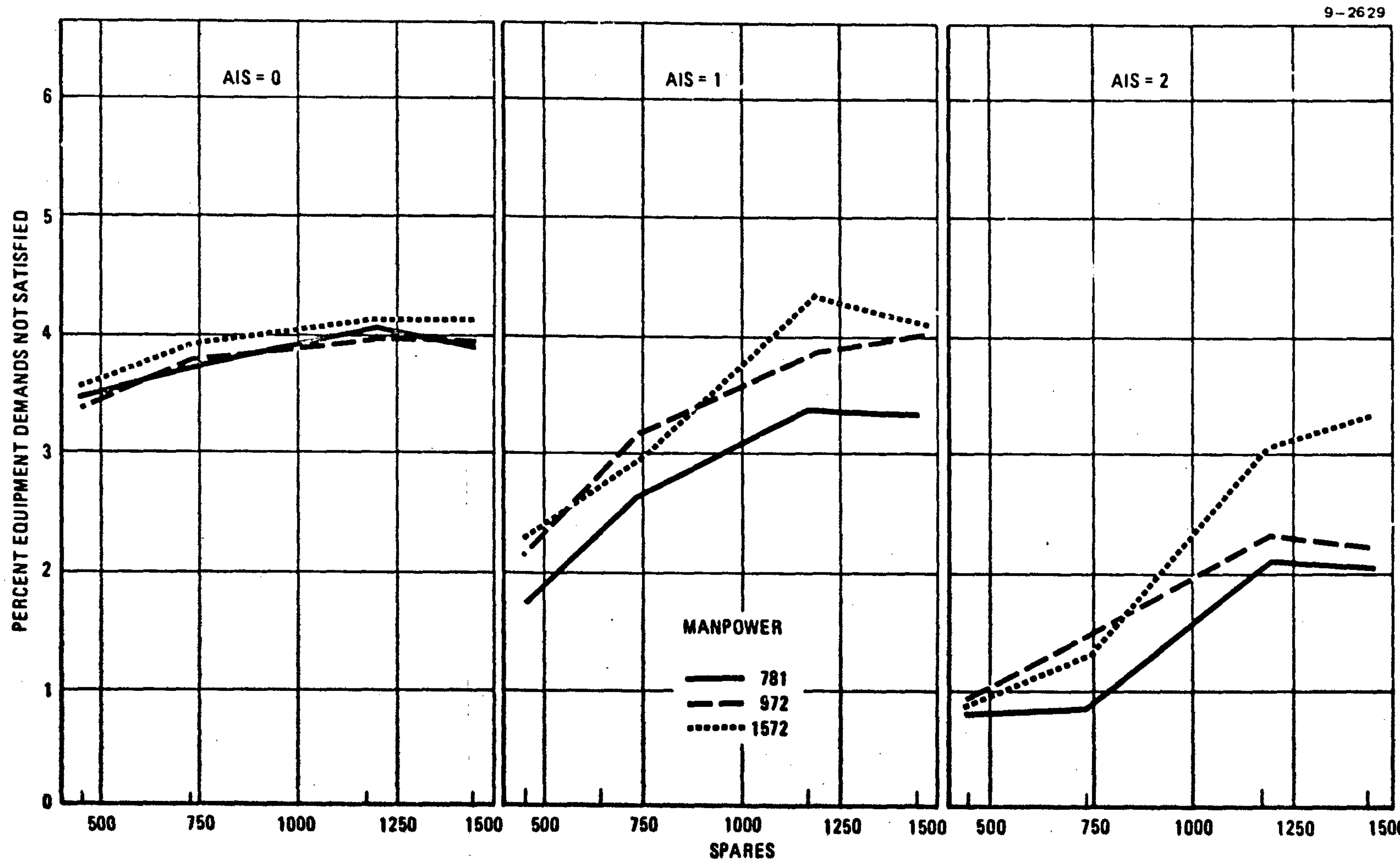

FIGURE E–6 PERCENT EQUIPMENT DEMANDS NOT SATISFIED AVERAGED OVER 30 DAYS FOR ALL RESOURCE CONDITIONS

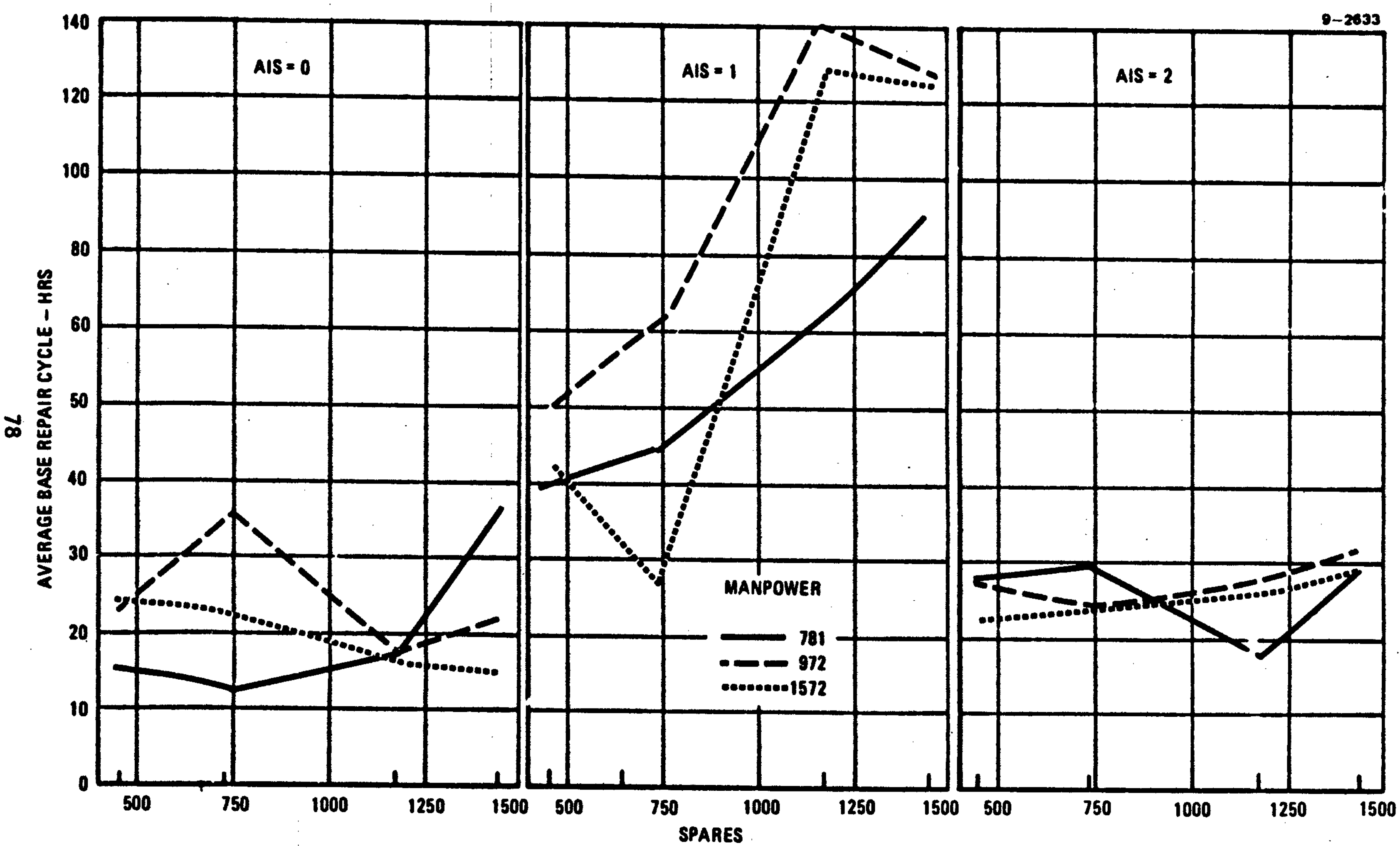

FIGURE E–7 AVERAGE BASE REPAIR CYCLE (HRS) AVERAGED OVER 30 DAYS FOR ALL RESOURCE CONDITIONS

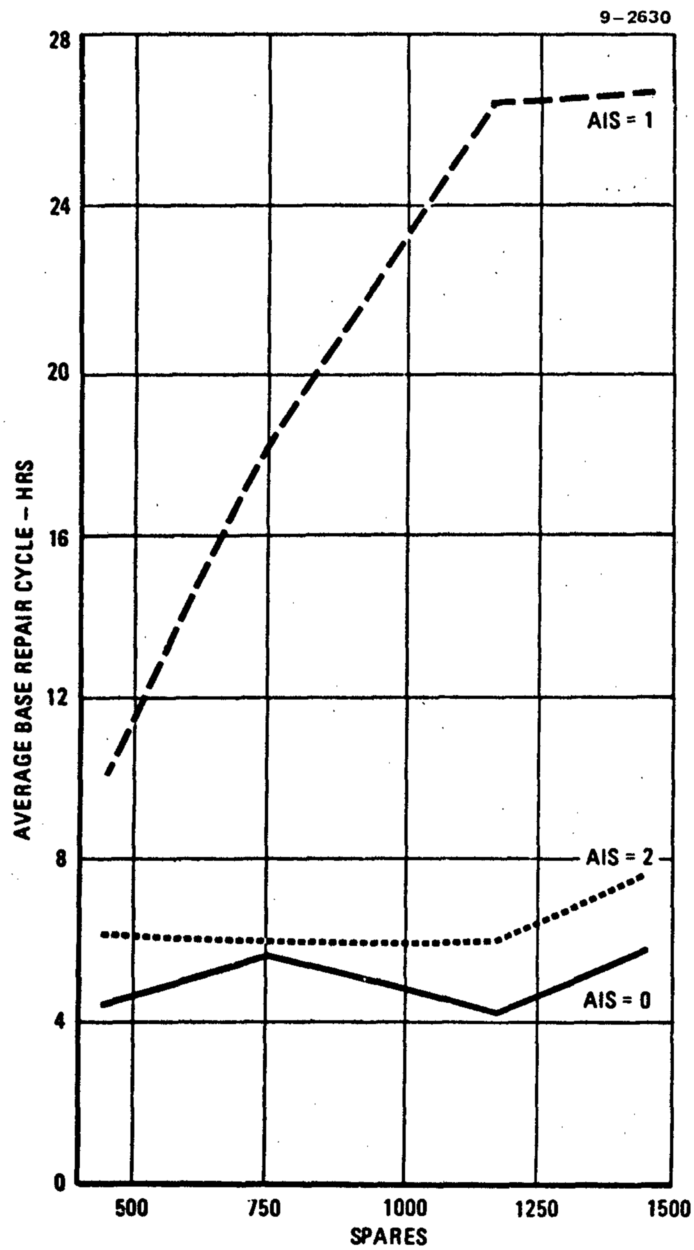

FIGURE E–8 AVERAGE BASE REPAIR CYCLE (HRS) AVERAGED OVER 30 DAYS FOR AIS AND SPARES RESOURCE CONDITIONS

APPENDIX F

SPARES X MANPOWER X SUPPORT EQUIPMENT: DISTRIBUTION OF VARIANCE (%) FOR REGRESSION EQUATION PREDICTORS

This Appendix identifies the predictors and associated variances for each of the dependent variables. The 26 predictors that were evaluated in the development of models of interaction are listed in the first column. A plurality of the predictors appeared in at least one regression equation. All 26 were listed in a consistent sequence so that anyone interested in a specific predictor can scan horizontally within the same area across the pages of data. The remaining columns identify the dependent variables. The second entry under dependent variable 20, for example, means that 26.34% of the variance in the dependent variable was attributed to manpower quantities. Summary statistics are provided for each dependent variable which identify number of predictors in an equation, variance due to the main effects of spares, manpower, and support equipment, variances attributed to these sources in two- and three-factor interactions, and total variance. These summary statistics are at the bottom of each table. In these tables due to space limitations, S2, M2, SE2, and R2 should be interpreted as S^2, M^2, SE^2, and R^2, respectively.

TABLE F-1 DISTRIBUTION OF VARIANCE (%) FOR REGRESSION EQUATION PREDICTORS, SPARES x MANPOWER x SUPPORT EQUIPMENT

		Categories of Dependent Variables							
		Operations		Aircraft					
Predictors		03	08	15	16	17	18	19	20
X1 Spares - 949.50 x .001	(S)	37.19	40.98	37.55	39.46	49.23	42.34	23.59	13.47
X2 Manpower - 1109.667 x .001	(M)	0.62	2.04	2.04					26.34
X3 Support Equipment	(SE)	2.59	4.35	4.68	4.07	5.13	5.83	1.11	3.18
X4 Spares Quadratic	(S2)	2.09	1.71	1.51	1.61	1.96	0.96	1.27	
X5 Manpower Quadratic	(M2)								9.42
X6 Support Equipment Quadratic	(SE2)				0.64	0.56	0.72		0.58
X7 S x M									7.94
X8 S x M2									2.05
X9 S2 x M									
X10 S2 x M2									
X11 S x SE					2.09	2.28	2.89		1.59
X12 S x SE2									0.41
X13 S2 x SE									
X14 S2 x SE2									
X15 M x SE									1.65
		03	08	15	16	17	18	19	20
X16 M x SE2									0.41
X17 M2 x SE									
X18 M2 x SE2									
X19 S x M x SE									0.72
X20 S x M x SE2			2.37						
X21 S x M2 x SE		0.95		2.46					
X22 S x M2 x SE2									
X23 S2 x M x SE									
X24 S2 x M x SE2									
X25 S2 x M2 x SE									
X26 S2 x M2 x SE2									
Number of Predictors in an Equation		5	5	5	5	5	5	3	12
% Variance Accounted For (R2 x 100)		43.44	51.45	48.24	47.87	59.16	52.74	25.97	67.76
Variance Sub-Totals									
Spares		39.28	42.69	39.06	41.07	51.19	43.30	24.86	13.47
Manpower		0.62	2.04	2.04	0.00	0.00	0.00	1.11	35.76
Support Equipment		2.59	4.35	4.68	4.71	5.69	6.55	0.00	3.76
Main Effects		42.49	49.08	45.78	45.78	56.88	49.85	25.97	52.99
2-Factor Interactions					2.09	2.28	2.89		14.05
3-Factor Interactions		0.95	2.37	2.46					0.72

TABLE F-1 DISTRIBUTION OF VARIANCE (%) FOR REGRESSION EQUATION PREDICTORS, SPARES x MANPOWER x SUPPORT EQUIPMENT (CONTINUED)

	Categories of Dependent Variables							
	Aircraft					Manpower		
Predictors	21	22	23	24	T8	28	29	30
X1 Spares - 949.50 x .001 (S)	31.52		37.33	37.55		27.67	36.73	2.32
X2 Manpower - 1109.667 x .001 (M)		16.23	2.02	2.04		26.13	2.65	
X3 Support Equipment (SE)	4.49		3.99	4.67		5.06	6.82	2.77
X4 Spares Quadratic (S2)	1.05		1.57	1.51		1.26	1.48	
X5 Manpower Quadratic (M2)		2.11						
X6 Support Equipment Quadratic(SE2)						1.03	1.32	3.11
X7 S x M		1.70				0.50		
X8 S x M2								
X9 S2 x M								
X10 S2 x M2								
X11 S x SE	1.73					1.67		
X12 S x SE2								
X13 S2 x SE								
X14 S2 x SE2								
X15 M x SE	4.28							
	21	22	23	24	T8	28	29	30
X16 M x SE2								
X17 M2 x SE								
X18 M2 x SE2	1.56	1.17						
X19 S x M x SE	0.61							
X20 S x M x SE2								
X21 S x M2 x SE	2.79		2.13	2.47			2.69	
X22 S x M2 x SE2								
X23 S2 x M x SE								
X24 S2 x M x SE2								
X25 S2 x M2 x SE								
X26 S2 x M2 x SE2								
Number of Predictors in an Equation	8	4	5	5	0	7	6	3
% Variance Accounted For (R2 x 100)	48.03	21.21	47.04	48.24	-	63.32	51.69	8.20
Variance Sub-Totals								
Spares	32.57	0.00	38.90	39.06		28.93	38.21	2.32
Manpower	0.00	18.34	2.02	2.04		26.13	2.65	0.00
Support Equipment	4.49	0.00	3.99	4.67		6.09	8.14	5.88
Main Effects	37.06	18.34	44.91	45.77		61.15	49.00	8.20
2-Factor Interactions	7.57	2.87				2.17		
3-Factor Interactions	3.40		2.13	2.47			2.69	

TABLE F-1 DISTRIBUTION OF VARIANCE (%) FOR REGRESSION EQUATION PREDICTORS, SPARES x MANPOWER x SUPPORT EQUIPMENT (CONTINUED)

	Categories of Dependent Variables							
	Manpower					Shop Repair		
Predictors	31	33	34	38	40	44	45	46
X1 Spares - 949.50 x .001 (S)	2.32	39.81	9.57		17.73	34.32		
X2 Manpower - 1109.667 x .001 (M)		2.43	50.55	50.62		2.38		
X3 Support Equipment (SE)	2.77	3.81	1.02	0.94		3.64		
X4 Spares Quadratic (S2)		1.67	0.26	0.26	1.15	1.52		
X5 Manpower Quadratic (M2			8.57	8.98				
X6 Support Equipment Quadratic(SE2)	3.11							
X7 S x M			3.37	3.41				
X8 S x M2			0.84	2.99				
X9 S2 x M								
X10 S2 x M2								
X11 S x SE			0.37	7.27				
X12 S x SE2								
X13 S2 x SE								
X14 S2 x SE2								
X15 M x SE								
	31	33	34	38	40	44	45	46
X16 M x SE2								
X17 M2 x SE								
X18 M2 x SE2								
X19 S x M x SE								
X20 S x M x SE2								
X21 S x M2 x SE		2.31				1.76		
X22 S x M2 x SE2								
X23 S2 x M x SE								
X24 S2 x M x SE2								
X25 S2 x M2 x SE								
X26 S2 x M2 x SE2								
Number of Predictors in an Equation	3	5	8	7	2	5	0	0
% Variance Accounted For (R2 x 100)	8.20	50.03	74.55	74.47	18.88	43.62	-	-
Variance Sub-Totals								
Spares	2.32	41.48	9.83	0.26	18.88	35.84		
Manpower	0.00	2.43	59.12	59.60	0.00	2.38		
Support Equipment	5.88	3.81	1.02	0.94	0.00	3.64		
Main Effects	47.72	69.97	60.80			41.86		
2-Factor Interactions		4.58	13.67					
3-Factor Interactions	2.31					1.76		

TABLE F-1 DISTRIBUTION OF VARIANCE (%) FOR REGRESSION EQUATION PREDICTORS, SPARES x MANPOWER x SUPPORT EQUIPMENT (CONTINUED)

	Categories of Dependent Variables							
	Shop Repair			Spares Supply				
Predictors	47	48	49	55	56	57	58	61
X1 Spares - 949.50 x .001 (S)	4.14			35.41	11.66	33.84	35.41	35.41
X2 Manpower - 1109.667 x .001 (M)	0.98	6.42	6.60	0.52	0.77	2.95	0.52	0.52
X3 Support Equipment (SE)	34.94	1.46		21.63	29.43	2.15	21.63	21.63
X4 Spares Quadratic (S2)				0.66		1.97	0.66	0.66
X5 Manpower Quadratic (M2	0.97							
X6 Support Equipment Quadratic(SE2)	1.47	3.78		2.02	8.28		2.02	2.02
X7 S x M								
X8 S x M2								
X9 S2 x M	0.75							
X10 S2 x M2								
X11 S x SE								
X12 S x SE2								
X13 S2 x SE								
X14 S2 x SE2								
X15 M x SE		1.01						
	47	48	49	55	56	57	58	61
X16 M x SE2								
X17 M2 x SE								
X18 M2 x SE2								
X19 S x M x SE								
X20 S x M x SE2								
X21 S x M2 x SE						2.16		
X22 S x M2 x SE2								
X23 S2 x M x SE								
X24 S2 x M x SE2								
X25 S2 x M2 x SE								
X26 S2 x M2 x SE2								
Number of Predictors in an Equation	6	4	1	5	4	5	5	5
% Variance Accounted For (R2 x 100)	43.25	12.67	6.60	60.24	50.14	43.07	60.24	60.24
Variance Sub-Totals								
Spares	4.14	0.00	0.00	36.07	11.66	35.81	36.07	36.07
Manpower	1.95	6.42	6.60	0.52	0.77	2.95	0.52	0.52
Support Equipment	36.41	5.24	0.00	23.65	37.71	2.15	23.65	23.65
Main Effects	42.50	11.66	6.60	60.24	50.14	40.91	60.24	60.24
2-Factor Interactions	0.75	1.01						
3-Factor Interactions						2.16		

TABLE F-1 DISTRIBUTION OF VARIANCE (%) FOR REGRESSION EQUATION PREDICTORS, SPARES x MANPOWER x SUPPORT EQUIPMENT (CONCLUDED)

	Categories of Dependent Variables							
	Spares Supply		Support Equipment					
Predictors	62	63	71	72	73	74	75	79
X1 Spares - 949.50 x .001 (S)	6.65	12.03		7.40		3.10	35.32	
X2 Manpower - 1109.667 x .001 (M)	1.91	0.85				0.68	2.04	
X3 Support Equipment (SE)	25.98	31.31	51.58	4.14	51.27	32.97	3.60	
X4 Spares Quadratic (S2)			0.33		0.33		1.28	0.65
X5 Manpower Quadratic (M2								
X6 Support Equipment Quadratic(SE2)	1.30	8.59	9.12	1.57	9.16	8.37		39.93
X7 S x M								
X8 S x M2								1.00
X9 S2 x M								
X10 S2 x M2								
X11 S x SE			15.89		16.24	3.52		16.94
X12 S x SE2			0.24		0.23	0.66		1.80
X13 S2 x SE								
X14 S2 x SE2								
X15 M x SE			1.02		1.00	0.75		1.94
	62	63	71	72	73	74	75	79
X16 M x SE2								
X17 M2 x SE	0.82							0.42
X18 M2 x SE2								
X19 S x M x SE								
X20 S x M x SE2			0.43		0.42			
X21 S x M2 x SE							1.48	
X22 S x M2 x SE2								
X23 S2 x M x SE								
X24 S2 x M x SE2								
X25 S2 x M2 x SE								
X26 S2 x M2 x SE2								
Number of Predictors in an Equation	5	4	7	3	7	7	5	7
% Variance Accounted For (R2 x 100)	36.66	52.78	78.61	13.11	78.65	50.05	43.72	62.68
Variance Sub-Totals								
Spares	6.65	12.03	0.33	7.40	0.33	3.10	36.60	0.65
Manpower	1.91	0.85	0.00	0.00	0.00	0.68	2.04	0.00
Support Equipment	27.28	39.90	60.70	5.71	60.43	41.34	3.60	39.93
Main Effects	35.84	52.78	61.03	13.11	60.76	45.12	42.24	40.58
2-Factor Interactions	0.82		17.15		17.47	4.93	1.48	22.10
3-Factor Interactions			0.43		0.42			

APPENDIX G

MODELS OF INTERACTION
SPARES X MANPOWER X SUPPORT EQUIPMENT

This Appendix provides the estimating models of interaction derived from the multiple regression analysis. The first term of each model represents the intercept followed by the regression coefficients associated with the predictors in the estimating model. The total variance is the percent of variation in the dependent variable that can be accounted for by the model. The standard error of estimate of 13.53, for example, computed for dependent variable 03, tells us that the estimated value can be expected to differ from the observed value within $\pm$13.53% in two out of three cases. In these tables due to space limitations, S2, M2, SE2, and R2 should be interpreted as S^2, M^2, SE^2, and R^2, respectively.

TABLE G-1 MODELS OF INTERACTION, SPARES x MANPOWER x SUPPORT EQUIPMENT

Percent Accomplished-Missions

Variable 03 = 78.5940 + 24.1222 (S) + 4.1231 (M) + 3.5384 (SE)
-26.9612 (S2) + 32.1211 (S x M2 x SE)

Total Variance (R2 x 100) = 43.44
Standard Error of Estimate = 13.53

Percent Accomplished-Sorties

Variable 08 = 55.9077 + 29.4092 (S) + 9.4359 (M) + 5.7461 (SE)
-30.6195 (S2) + 63.3809 (S x M2 x SE)

Total Variance (R2 x 100) = 51.45
Standard Error of Estimate = 15.71

Percent on Sorties (Including Alert)

ble 15 = 9.8871 + 5.4106 (S) + 1.8419 (M) + 1.1634 (SE)
-5.6145 (S2) + 12.6627 (S x M2 x SE)

tal Variance (R2 x 100) = 48.24
Standard Error of Estimate = 3.17

Percent in Unscheduled Maintenance-Aircraft

Variable 16 = 21.2553 + 10.6906 (S) + 5.4674 (SE) - 12.3678 (S2)
- 1.5791 (SE2) + 4.3058 (S x SE)

Total Variance (R2 x 100) = 47.87
Standard Error of Estimate = 6.77

TABLE G-1 MODELS OF INTERACTION, SPARES x MANPOWER x SUPPORT EQUIPMENT (CONTINUED)

Percent in Scheduled Maintenance-Aircraft

Variable 17 = 7.4652 + 3.0192 (S) + 1.3737 (SE) - 3.3487 (S2) -0.3673 (SE2) + 1.1112 (S x SE)

Total Variance (R2 x 100) = 59.16
Standard Error of Estimate = 1.48

Percent in NORS

Variable 18 = 41.3708 - 33.7117 (S) - 19.6121 (SE) + 30.4348 (S2) + 5.3857 (SE2) - 16.2327 (S x SE)

Total Variance (R2 x 100) = 52.74
Standard Error of Estimate = 20.62

Percent in Mission Wait Status

Variable 19 = 0.3790 + 0.1687 (S) + 0.0176 (SE) - 0.1603 (S2)

Total Variance (R2 x 100) = 25.97
Standard Error of Estimate = 0.12

TABLE G-1 MODELS OF INTERACTION, SPARES x MANPOWER x SUPPORT EQUIPMENT (CONTINUED)

Percent in Service Plus Waiting

Variable 20 = -2.4827 - 3.5180 (S) - 18.2918 (M) - 4.9961 (SE)
+53.6130 (M2) - 1.4889 (SE2) + 24.4920 (S x M)
+65.0333 (S x M2) + 10.2582 (S x SE) - 3.2741 (S x SE2)
-11.6037 (M x SE) + 3.6703 (M x SE2) + 7.3579 (S x M x SE)

Total Variance (R2 x 100) = 48.03
Standard Error of Estimate = 5.27

Percent in Operationally Ready

Variable 21 = 16.5194 + 9.8780 (S) + 4.8273 (SE) - 11.0604 (S2)
+ 7.4[illegible]72 (S x SE) + 7.9308 (M x SE) - 9.2080 (M2 x SE2)
+13.6[illegible]78 (S x M x SE) - 20.7373 (S x M2 x SE)

Total Variance R2 x 100) = 48.03
Standard Error of Estimate = 7.51

Average Aircraft Post-Sortie Time (Hours)

Variable 22 = 5.0713 - 3.3467 (M) + 6.9267 (M2) - 1.9771 (S x M)

Total Variance (R2 x 100) = 21.21
Standard Error of Estimate = 1.76

TABLE G-1 MODELS OF INTERACTION, SPARES x MANPOWER x SUPPORT EQUIPMENT (CONTINUED)

Average Number of Sorties Per Aircraft Per Day

Variable 23 = 1.6363 + 0.8433 (S) + 0.2818 (M) + 0.1651 (SE) -0.8795 (S2) + 1.8089 (S x M2 x SE)

Total Variance (R2 x 100) = 47.04
Standard Error of Estimate = 0.49

Flying Hours

Variable 24 = 170.8526 + 93.4934 (S) + 31.8272 (M) + 20.1033 (SE) - 97.0200 (S2) + 218.8014 (S x M2 x SE)

Total Variance (R2 x 100) = 48.24
Standard Error of Estimate = 54.78

Average Aircraft Post-Sortie Time (Hours)

Variable T8 = No predictors met the 0.001 significance level for entry into the model.

Percent Utilization-Manpower

Variable 28 = 19.3263 + 8.1061 (S) - 13.0888 (M) + 6.1585 (SE) -10.1854 (S2) - 1.8785 (SE2) - 4.7171 (S x M) +3.5915 (S x SE)
Total Variance (R2 x 100) = 63.32
Standard Error of Estimate = 5.30

TABLE G-1 MODELS OF INTERACTION, SPARES x MANPOWER x SUPPORT EQUIPMENT (CONTINUED)

Manhours Used (x100)

Variable 29 = 23.8633 + 11.5763 (S) + 4.6196 (M) + 7.7918 (SE)
-12.2242 (S2) - 2.3526 (SE2) + 29.0241 (S x M2 x SE)

Total Variance (R2 x 100) = 51.69
Standard Error of Estimate = 6.73

Percent Unscheduled Maintenance-Manpower

Variable 30 = 66.5517 + 1.7388 (S) + 4.1726 (SE) - 1.6393 (SE2)

Total Variance (R2 x 100) = 8.20
Standard Error of Estimate = 4.21

Percent Scheduled Maintenance-Manpower

Variable 31 = 33.4483 - 1.7388 (S) - 4.1726 (SE) + 1.6393 (SE2)
Total Variance (R2 x 100) = 8.20
Standard Error of Estimate = 4.21

Number of Personnel Demanded

Variable 33 = 3000.9105 + 1441.1122 (S) + 512.9174 (M) + 267.4306 (SE)
- 1504.1399 (S2) + 3118.3863 (S x M2 x SE)

Total Variance (R2 x 100) = 50.03
Standard Error of Estimate = 793.09

TABLE G-1 MODELS OF INTERACTION, SPARES x MANPOWER x SUPPORT EQUIPMENT (CONTINUED)

Percent Personnel Available (Prime)

Variable 34 = 95.0970 - 0.8880 (S) + 37.3629 (M) - 1.4836 (SE)
+ 6.3717 (S2) - 66.6071 (M2) + 26.9144 (S x M)
-54.4937 (S x M2) - 2.3296 (S x SE)

Total Variance (R2 x 100) = 74.55
Standard Error of Estimate = 6.08

Percent Demands Not Satisfied-Manpower

Variable 38 = 4.4523 - 36.7132 (M) + 1.3878 (SE) - 6.2581 (S2)
+66.4679 (M2) - 27.1309 (S x M) + 57.5503 (S x M2)
+ 2.2795 (S x SE)

Total Variance (R2 x 100) = 74.47
Standard Error of Estimate = 5.94

Simulated Maintenance Manhours Per Flying Hour

Variable 40 = 15.0260 - 2.8164 (S) + 2.9376 (S2)

Total Variance (R2 x 100) = 18.88
Standard Error of Estimate = 2.37

TABLE G-1 MODELS OF INTERACTION, SPARES x MANPOWER x SUPPORT EQUIPMENT (CONTINUED)

Number of Reparable Generations

Variable 44 = 60.4415 + 31.1735 (S) + 11.6426 (M) + 6.0097 (SE)
-32.9250 (S2) + 62.6401 (S x M2 x SE)

Total Variance (R2 x 100) = 43.62
Standard Error of Estimate = 19.36

Percent Base Repair

Variable 45 = No predictors met the 0.001 significance level for entry into the model.

Percent Depot Repair

Variable 46 = No predictors met the 0.001 significance level for entry into the model.

Average Base Repair Cycle

Variable 47 = 0.3174 + 0.2531 (S) + 0.4891 (M) + 1.2477 (SE)
- 0.8882 (M2) - 0.6100 (SE2) - 1.2624 (S2 x M)

Total Variance (R2 x 100) = 43.25
Standard Error of Estimate = 0.36

TABLE G-1 MODELS OF INTERACTION, SPARES x MANPOWER x SUPPORT EQUIPMENT (CONTINUED)

Percent Active Repair

Variable 48 = 88.8094 + 15.2241 (M) + 13.3658 (SE) - 5.6659 (SE2) - 4.9893 (M x SE)

Total Variance (R2 x 100) = 12.67
Standard Error of Estimate = 12.88

Percent White Space

Variable 49 = 6.8050 - 9.2221 (M)

Total Variance (R2 x 100) = 6.60
Standard Error of Estimate = 11.82

Percent Fill Rate

Variable 55 = 82.2539 + 14.3406 (S) - 1.9926 (M) + 10.9843 (SE) - 7.9125 (S2) - 2.8216 (SE2)

Total Variance (R2 x 100) = 60.24
Standard Error of Estimate = 5.93

Number of Backorder Days-Spares Supply

Variable 56 = 281.5991 - 143.4378 (S) + 41.5342 (M) - 304.2397 (SE) + 98.5019 (SE2)

Total Variance (R2 x 100) = 50.14
Standard Error of Estimate = 114.22

TABLE G-1 MODELS OF INTERACTION, SPARES x MANPOWER x SUPPORT EQUIPMENT (CONTINUED)

Number of Units Demanded-Spares Supply

Variable 57 = 257.6799 + 115.5505 (S) + 49.8925 (M) + 17.7792 (SE) -144.5101 (S2) + 267.2369 (S x M2 x SE)

Total Variance (R2 x 100) = 43.07
Standard Error of Estimate = 74.89

Percent Units Off-The-Shelf

Variable 58 = 82.2539 + 14.3406 (S) - 1.9926 (M) + 10.9843 (SE) - 7.9125 (S2) - 2.8216 (SE2)

Total Variance (R2 x 100) = 60.24
Standard Error of Estimate = 5.93

Percent Demands Not Satisfied-Spares Supply

Variable 61 = 17.7460 - 14.3405 (S) + 1.9927 (M) - 10.9844 (SE) + 7.9126 (S2) + 2.8217 (SE2)

Total Variance (R2 x 100) = 60.24
Standard Error of Estimat = 5.93

Number of Cannibalizations

Variable 62 = 19.3667 - 7.3614 (S) + 6.6011 (M) - 10.8041 (SE) + 2.6542 (SE2) - 11.6752 (M2 x SE)

Total Variance (R2 x 100) = 36.66
Standard Error of Estimate = 8.75

TABLE G-1 MODELS OF INTERACTION, SPARES x MANPOWER x SUPPORT EQUIPMENT (CONTINUED)

Number of Items on Backorder-Spares Supply

Variable 63 = 297.2861 - 148.9567 (S) + 44.6450 (M) -318.2986 (SE) + 102.6097 (SE2)

Total Variance (R2 x 100) = 52.78
Standard Error of Estimate = 113.65

Equipment Percent Used-Unscheduled Maintenance

Variable 71 = 0.0933 + 0.5628 (SE) - 0.1525 (S2) - 0.1668 (SE2) + 0.3219 (S x SE) - 0.0637 (S x SE2) + 0.0596 (M x SE) + 0.0551 (S x M x SE2)

Total Variance (R2 x 100) = 78.61
Standard Error of Estimate = 0.12

Equipment Percent Used-Scheduled Maintenance

Variable 72 = 0.0075 + 0.0094 (S) + 0.0104 (SE) - 0.0035 (SE2)

Total Variance (R2 x 100) = 13.11
Standard Error of Estimate = 0.01

TABLE G-1 MODELS OF INTERACTION, SPARES x MANPOWER x SUPPORT EQUIPMENT (CONTINUED)

Equipment Percent Unused

Variable 73 = 99.8997 - 0.5750 (SE) + 0.1537 (S2) + 0.1709 (SE2)
- 0.3301 (S x SE) + 0.0645 (S x SE2) - 0.0604 (M x SE)
- 0.0556 (S x M x SE)

Total Variance (R2 x 100) = 78.65
Standard Error of Estimate = 0.12

Number of Backorder Days-Support Equipment

Variable 74 = 553.9201 + 473.1200 (S) + 217.6133 (M)
-757.2086 (SE) + 240.6503 (SE2) - 585.5241 (S x SE)
+175.3573 (S x SE2) - 122.8342 (M x SE)

Total Variance (R2 x 100) = 50.05
Standard Error of Estimate = 278.30

Number of Units Demanded-Support Equipment

Variable 75 = 704.8839 + 387.8356 (S) + 129.1243 (M) + 71.4486 (SE)
+361.6835 (S2) + 685.9198 (S x M2 x SE)

Total Variance (R2 x 100) = 43.72
Standard Error of Estimate = 231.35

TABLE G-1 MODELS OF INTERACTION, SPARES x MANPOWER x SUPPORT EQUIPMENT (CONCLUDED)

Equipment Percent Demands Not Satisfied

Variable 79 = 3.9731 - 1.1484 (S2) - 0.4435 (SE2) + 3.2780 (S x M2)
+2.1915 (S x SE) - 0.7224 (S x SE2) + 0.6581 (M x SE)
-1.2194 (M2 x SE)

Total Variance (R2 x 100) = 62.68
Standard Error of Estimate = 0.84

APPENDIX H

SPARES X MANPOWER X SUPPORT EQUIPMENT X DAYS: DISTRIBUTION OF VARIANCE (%) FOR REGRESSION EQUATION PREDICTORS

This Appendix identifies the predictors and associated variances for each of the dependent variables. The 80 predictors that were evaluated in the development of models of interaction are listed in the first column. A plurality of the predictors appeared on at least one regression equation. All 80 were listed in a consistent sequence so that anyone interested in a specific predictor can scan horizontally within the same area across the pages of data. The remaining columns identify the dependent variables. The first entry under dependent variable 03, for example, means that 37.19% of the variance in this dependent variable was attributed to spares quantities. Summary statistics are provided for each dependent variable which identify number of predictors in an equation, variance due to the main effects of spares, manpower, support equipment, and days, variances attributed to these sources in 2-, 3-, and 4-factor interactions, and total variance. These summary statistics are on pages H-4, H-7, H-10, H-13, and H-16. Due to space limitations in these tables, S2, M2, SE2, D2, and R2 should be interpreted as S^2, M^2, SE^2, D^2, and R^2, respectively.

TABLE H-1 DISTRIBUTION OF VARIANCE (%) FOR REGRESSION EQUATION PREDICTORS, SPARES x MANPOWER x SUPPORT EQUIPMENT x DAYS

		Categories of Dependent Variables							
		Operations		Aircraft					
Predictors		03	08	15	16	17	.18	19	20
X1 Spares - 949.50 x .001	(S)	37.19	40.98	37.55	39.46	49.23	42.34	23.59	13.47
X2 Manpower - 1109.667 x .001	(M)	0.61	2.04	2.04		0.22	0.31	0.24	26.34
X3 Support Equipment	(SE)	2.60	4.36	4.68	4.07	5.13	5.83		3.19
X4 Spares Quadratic	(S2)	2.09	1.71	1.51	1.62	1.95	0.95	1.28	
X5 Manpower Quadratic	(M2)					0.48	0.20		9.42
X6 Support Equipment Quadratic	(SE2)	0.42	0.49	0.50	0.63	0.57	0.72		0.58
X7 S x M			0.34	0.35					7.94
X8 S x M2									2.04
X9 S2 x M									
X10 S2 x M2									
X11 S x SE			0.39	0.43	2.08	2.29	2.90		1.59
X12 S x SE2			0.16	0.18	0.17		0.16		0.21
X13 S2 x SE									
X14 S2 x SE2									
X15 M x SE			0.10						1.65
		03	08	15	16	17	18	19	20
X16 M x SE2									0.41
X17 M2 x SE			0.16						
X18 M2 x SE2									
X19 S x M x SE			0.10		0.35				0.72
X20 S x M x SE2									0.16
X21 S x M2 x SE		0.95	2.36	2.46		0.43		0.27	
X22 S x M2 x SE2									
X23 S2 x M x SE			0.13	0.16					
X24 S2 x M x SE2									
X25 S2 x M2 x SE									
X26 S2 x M2 x SE2									
X27 Day - 15.5	(D)	32.04	26.18	31.62	32.03	11.62	31.68	38.32	
X28 Day Quadratic	(D2)								0.63
X29 S x D		14.02	8.82	6.85	7.92	9.91	0.64	11.34	
X30 S x D2							0.16		

TABLE H-1 DISTRIBUTION OF VARIANCE (%) FOR REGRESSION EQUATION PREDICTORS, SPARES x MANPOWER x SUPPORT EQUIPMENT x DAYS (CONTINUED)

	Categories of Dependent Variables							
	Operations		Aircraft					
Predictors	03	08	15	16	17	18	19	20
X31 S2 x D								
X32 S2 x D2			0.70	0.58		0.93		
X33 M x D		0.56	0.56	0.14				3.51
X34 M x D2								0.48
X35 M2 x D							0.49	7.29
X36 M2 x D2								0.48
X37 SE x D	0.29						0.33	
X38 SE x D2				0.10			2.32	
X39 SE2 x D	0.13						0.22	
X40 SE2 x D2		0.18						
X41 S x M x D								
X42 S x M x D2								
X43 S x M2 x D								
X44 S x M2 x D2		0.43	0.52	0.15				
X45 S2 x M x D								
X46 S2 x M x D2								
X47 S2 x M2 x D								
X48 S2 x M2 x D2					0.51		0.76	
X49 S x SE x D		0.59	0.63	0.58	0.73	6.50		
X50 S x SE x D2								0.35
X51 S x SE2 x D								1.28
X52 S x SE2 x D2				0.38		0.68		0.82
X53 S2 x SE x D		0.58	0.62	0.62	0.81	0.99		0.71
X54 S2 x SE x D2								
X55 S2 x SE2 x D			0.11			0.12		
X56 S2 x SE2 x D2		0.32						
X57 M x SE x D								
X58 M x SE x D2				0.16				
X59 M x SE2 x D2								
X60 M x SE2 x D2			0.14					

TABLE H-1 DISTRIBUTION OF VARIANCE (%) FOR REGRESSION EQUATION PREDICTORS, SPARES x MANPOWER x SUPPORT EQUIPMENT x DAYS (CONTINUED)

	Categories of Dependent Variables							
	Operations		Aircraft					
Predictors	03	08	15	16	17	18	19	20
X61 M2 x SE x D	0.15							
X62 M2 x SE x D2	0.16		0.10	0.38				
X63 M2 x SE2 x D	0.22							
X64 M2 x SE2 x D2								
X65 S x M x SE x D								0.93
X66 S x M x SE x D2								0.19
X67 S x M x SE2 x D								
X68 S x M x SE2 x D2								0.37
X69 S x M2 x SE x D	0.35	0.10	0.09				0.37	0.58
X70 S x M2 x SE x D2								
	03	08	15	16	17	18	19	20
X71 S x M2 x SE2 x D								
X72 S x M2 x SE2 x D2					0.43			
X73 S2 x M x SE x D								0.45
X74 S2 x M x SE x D2				0.23				
X75 S2 x M x SE2 x D			0.09					
X76 S2 x M x SE2 x D2								
X77 S2 x M2 x SE x D								
X78 S2 x M2 x SE x D2	0.39							
X79 S2 x M2 x SE2 x D	0.11							
X80 S2 x M2 x SE2 x D2								
Number of Predictors in an Equation	16	22	22	19	14	16	12	27
% of Variance Accounted for (R2 x 100)	91.72	91.08	91.89	91.65	84.31	95.11	79.53	85.79
Variance Sub-Totals								
Spares	39.28	42.69	39.06	41.08	51.18	43.29	24.87	13.47
Manpower	0.61	2.04	2.04	0.00	0.70	0.51	0.24	35.76
Support Equipment	3.02	4.85	5.18	4.70	5.70	6.55	0.00	3.77
Day	32.04	26.18	31.62	32.03	11.62	31.68	38.32	0.63
Main Effects	74.95	75.76	77.90	77.81	69.20	82.03	63.43	53.63
2-Factor Interactions	14.44	11.03	9.07	10.99	12.20	4.79	14.70	25.60
3-Factor Interactions	1.48	4.19	4.74	2.62	2.48	8.29	1.03	4.04
4-Factor Interactions	0.85	0.10	0.18	0.23	0.43		0.37	2.52
	16.77	15.32	13.99	13.84	15.11	13.08	16.10	32.16

TABLE H-1 DISTRIBUTION OF VARIANCE (%) FOR REGRESSION EQUATION PREDICTORS, SPARES x MANPOWER x SUPPORT EQUIPMENT x DAYS (CONTINUED)

		Categories of Dependent Variables							
		Aircraft					Manpower		
Predictors		21	22	23	24	18	28	29	30
X1 Spares - 949.50 x .001	(S)	31.52		37.33	37.55		27.67	36.73	
X2 Manpower - 1109.667 x .001	(M)	0.35	16.23	2.02	2.03		26.13	2.66	
X3 Support Equipment	(SE)	4.50		3.98	4.68		5.06	6.82	2.77
X4 Spares Quadratic	(S2)	1.05		1.57	1.51		1.26	1.49	
X5 Manpower Quadratic	(M2)	0.17	2.11					0.36	
X6 Support Equipment Quadratic	(SE2)			0.45	0.50		1.03	1.32	3.10
X7 S x M			1.70	0.29	0.35		0.50		
X8 S x M2									
X9 S2 x M									
X10 S2 x M2							0.20		
X11 S x SE		1.72		0.37	0.43		1.67	2.58	
X12 S x SE2				0.16	0.19		0.09	0.09	
X13 S2 x SE									
X14 S2 x SE2		0.10							
X15 M x SE		4.27							
		21	22	23	24	18	28	29	30
X16 M x SE2									
X17 M2 x SE									
X18 M2 x SE2		1.56	1.17						
X19 S x M x SE		0.61		0.10				1.30	
X20 S x M x SE2									
X21 S x M2 x SE		2.79		2.14	2.47				
X22 S x M2 x SE2				0.08					
X23 S2 x M x SE					0.15				
X24 S2 x M x SE2									
X25 S2 x M2 x SE									
X26 S2 x M2 x SE2		0.15							
X27 Day - 15.5	(D)	33.05		33.18	31.62		18.31	24.54	1.56
X28 Day Quadratic	(D2)		1.45						
X29 S x D		0.50		7.93	6.85		8.18	10.19	7.74
X30 S x D2									5.05

TABLE H-1 DISTRIBUTION OF VARIANCE (%) FOR REGRESSION EQUATION PREDICTORS, SPARES x MANPOWER x SUPPORT EQUIPMENT x DAYS (CONTINUED)

	Categories of Dependent Variables							
	Aircraft					Manpower		
Predictors	21	22	23	24	T8	28	29	30
X31 S2 x D								22.39
X32 S2 x D2	1.01		0.73	0.70				2.70
X33 M x D	1.17		0.66	0.56		0.12	0.69	
X34 M x D2						0.21		
X35 M2 x D								
X36 M2 x D2								
X37 SE x D								
X38 SE x D2								
X39 SE2 x D								
X40 SE2 x D2								
X41 S x M x D						0.44		
X42 S x M x D2								
X43 S x M2 x D						0.13		
X44 S x M2 x D2			0.34	0.52				
X45 S2 x M x D								
	21	22	23	24	T8	28	29	30
X46 S2 x M x D2								
X47 S2 x M2 x D								
X48 S2 x M2 x D2								
X49 S x SE x D	4.52		0.53	0.63		0.53	0.77	
X50 S x SE x D2								
X51 S x SE2 x D								
X52 S x SE2 x D2								
X53 S2 x SE x D			0.53	0.62			0.41	
X54 S2 x SE x D2						0.25	0.37	
X55 S2 x SE2 x D				0.11				
X56 S2 x SE2 x D2								
X57 M x SE x D								
X58 M x SE x D2							0.20	
X59 H x SE2 x D2								
X60 M x SE2 x D2				0.14				

TABLE H-1 DISTRIBUTION OF VARIANCE (%) FOR REGRESSION EQUATION PREDICTORS, SPARES x MANPOWER x SUPPORT EQUIPMENT x DAYS (CONTINUED)

	Categories of Dependent Variables							
	Aircraft					Manpower		
Predictors	21	22	23	24	18	28	29	30
X61 M2 x SE x D								
X62 M2 x SE x D2			0.18	0.10		0.13	0.14	
X63 M2 x SE2 x D								
X64 M2 x SE2 x D2								
X65 S x M x SE x D								
X66 S x M x SE x D2								
X67 S x M x SE2 x D								
X68 S x M x SE2 x D2								
X69 S x M2 x SE x D			0.09	0.09			0.16	
X70 S x M2 x SE x D2								
	21	22	23	24	18	28	29	30
X71 S x M2 x SE2 x D								
X72 S x M2 x SE2 x D2	0.54						0.38	
X73 S2 x M x SE x D								
X74 S2 x M x SE x D2			0.14					
X75 S2 x M x SE2 x D			0.07	0.09			0.11	
X76 S2 x M x SE2 x D2								
X77 S2 x M2 x SE x D	0.70					0.32		
X78 S2 x M2 x SE x D2								
X79 S2 x M2 x SE2 x D								
X80 S2 x M2 x SE2 x D2								
Number of Predictors in an Equation	19	5	22	22	0	19	20	7
% of Variance Accounted for (R2 x 100)	90.28	22.56	92.87	91.89	0.00	92.23	91.31	45.31
Variance Sub-Totals								
Spares	32.57	0.00	38.90	39.06		28.93	38.22	0.00
Manpower	0.52	18.24	2.02	2.03		26.13	3.02	0.00
Support Equipment	4.50	0.00	4.43	5.18		6.09	8.14	5.87
Day	33.05	1.45	33.18	31.62		18.31	24.54	1.56
Main Effects	70.64	19.69	78.53	77.89		79.46	73.92	7.43
2-Factor Interactions	10.33	2.87	10.14	9.08		10.97	13.55	37.88
3-Factor Interactions	8.07		3.90	4.74		1.48	3.19	
4-Factor Interactions	1.24		0.30	0.18		0.32	0.65	
	19.64	2.87	14.34	14.00		12.77	17.39	37.88

TABLE H-1 DISTRIBUTION OF VARIANCE (%) FOR REGRESSION EQUATION PREDICTORS, SPARES x MANPOWER x SUPPORT EQUIPMENT x DAYS (CONTINUED)

Predictors		Categories of Dependent Variables: Manpower					Shop Repair		
		31	33	34	38	40	44	45	46
X1 Spares - 949.50 x .001	(S)		39.81	9.57	9.06	17.73	34.32		
X2 Manpower - 1109.667 x .001	(M)		2.43	50.55	50.62		2.37		
X3 Support Equipment	(SE)	2.77	3.81	1.02	0.93		3.65		
X4 Spares Quadratic	(S2)		1.67	0.26	0.26	1.15	1.51		
X5 Manpower Quadratic	(M2)			8.57	8.98		0.23		
X6 Support Equipment Quadratic	(SE2)	3.10	0.43				0.39		
X7 S x M			0.32	3.37	3.41	0.59			
X8 S x M2				0.84	0.88				
X9 S2 x M				0.10	0.11				
X10 S2 x M2									
X11 S x SE			0.37	0.37	0.34		0.29		
X12 S x SE2			0.16						
X13 S2 x SE									
X14 S2 x SE2									
X15 M x SE									
X16 M x SE2									
X17 M2 x SE									
X18 M2 x SE2				0.19	0.18				
X19 S x M x SE			0.18				0.49		
X20 S x M x SE2									
X21 S x M2 x SE			2.31				1.77		
X22 S x M2 x SE2									
X23 S2 x M x SE									
X24 S2 x M x SE2									
X25 S2 x M2 x SE									
X26 S2 x M2 x SE2									
X27 Day - 15.5	(D)	1.56	28.34	9.36	9.33	22.41	30.65		
X28 Day Quadratic	(D2)								
X29 S x D		7.74	8.97	2.83	2.68	3.86	7.61		
X30 S x D2		5.05							

TABLE H-1 DISTRIBUTION OF VARIANCE (%) FOR REGRESSION EQUATION PREDICTORS, SPARES x MANPOWER x SUPPORT EQUIPMENT x DAYS (CONTINUED)

	Categories of Dependent Variables							
	Manpower					Shop Repair		
Predictors	31	33	34	38	40	44	45	46
X31 S2 x D	22.39							
X32 S2 x D2	2.70	0.26	0.37	0.43		0.58		
X33 M x D		0.80	3.29	3.44		0.84		
X34 M x D2					0.61			
X35 M2 x D			0.58	0.62				
X36 M2 x D2					0.74			
X37 SE x D					0.57			
X38 SE x D2								
X39 SE2 x D								
X40 SE2 x D2								
X41 S x M x D			1.64	1.59				
X42 S x M x D2								
X43 S x M2 x D			0.85	0.88				
X44 S x M2 x D2		0.39						
X45 S2 x M x D								
	31	33	34	38	40	44	45	46
X46 S2 x M x D2								
X47 S2 x M2 x D								
X48 S2 x M2 x D2			0.14	0.14				
X49 S x SE x D		0.58	0.16	0.14		0.57		
X50 S x SE x D2								
X51 S x SE2 x D								
X52 S x SE2 x D2								
X53 S2 x SE x D		0.61	0.11	0.11		0.62		
X54 S2 x SE x D2		0.12						
X55 S2 x SE2 x D								
X56 S2 x SE2 x D2								
X57 M x SE x D								
X58 M x SE x D2		0.13				0.23		
X59 M x SE2 x D								
X60 M x SE2 x D2								

TABLE H-1 DISTRIBUTON OF VARIANCE (%) FOR REGRESSION EQUATION PREDICTORS, SPARES x MANPOWER x SUPPORT EQUIPMENT x DAYS (CONTINUED)

	Categories of Dependent Variables							
	Manpower					Shop Repair		
Predictors	31	33	34	38	40	44	45	46
X61 M2 x SE x D								
X62 M2 x SE x D2								
X63 M2 x SE2 x D		0.27				0.33		
X64 M2 x SE2 x D2								
X65 S x M x SE x D								
X66 S x M x SE x D2								
X67 S x M x SE2 x D								
X68 S x M x SE2 x D2								
X69 S x M2 x SE x D								
X70 S x M2 x SE x D2		0.11						
	21	22	23	24	18	28	29	30
X71 S x M2 x SE2 x D								
X72 S x M2 x SE2 x D2								
X73 S2 x M x SE x D			0.06			0.30		
X74 S2 x M x SE x D2								
X75 S2 x M x SE2 x D		0.20						
X76 S2 x M x SE2 x D2		0.10						
X77 S2 x M2 x SE x D								
X78 S2 x M2 x SE x D2								
X79 S2 x M2 x SE2 x D								
X80 S2 x M2 x SE2 x D2								
Number of Predictors in an Equation	7	23	21	20	8	18	0	0
% of Variance Accounted for (R2x100)	45.31	92.37	94.23	94.13	47.66	86.75	0.00	0.00
Variance Sub-Totals								
Spares	0.00	41.48	9.83	9.32	18.88	35.83		
Manpower	0.00	2.43	59.12	59.60	0.00	2.60		
Support Equipment	5.87	4.24	1.02	0.93	0.00	4.04		
Day	1.56	28.34	9.36	9.33	22.41	30.65		
Main Effects	7.43	76.49	79.33	79.18	41.29	73.12		
2-Factor Interactions	37.88	10.88	11.94	12.09	6.37	9.32		
3-Factor Interactions		4.59	2.90	2.86		4.01		
4-Factor Interactions		0.41	0.06			0.30		
	37.88	15.88	14.90	14.95	6.37	13.63		

TABLE H-1 DISTRIBUTION OF VARIANCE (%) FOR REGRESSION EQUATION PREDICTORS, SPARES x MANPOWER x SUPPORT EQUIPMENT x DAYS (CONTINUED)

		Categories of Dependent Variables							
		Shop Repair			Spares Supply				
Predictors		47	48	49	55	56	57	58	61
X1 Spares - 949.50 x .001	(S)	4.14			35.41	11.66	33.84	35.41	35.41
X2 Manpower - 1109.667 x .001	(M)	0.99	6.42	6.60	0.52	0.77	2.95	0.52	0.52
X3 Support Equipment	(SE)	34.94			21.63	29.43	2.15	21.63	21.63
X4 Spares Quadratic	(S2)					0.05	1.97		
X5 Manpower Quadratic	(M2)	0.96				0.01			
X6 Support Equipment Quadratic	(SE2)	1.47			2.01	8.27	0.29	2.01	2.01
X7 S x M						0.02			
X8 S x M2									
X9 S2 x M		0.75							
X10 S2 x M2									
X11 S x SE							1.87		
X12 S x SE2							0.17		
X13 S2 x SE						0.23			
X14 S2 x SE2									
X15 M x SE			1.02			0.03			
		47	48	49	55	56	57	58	61
X16 M x SE2									
X17 M2 x SE						0.32	0.24		
X18 M2 x SE2									
X19 S x M x SE						0.03	1.20		
X20 S x M x SE2						0.01			
X21 S x M2 x SE									
X22 S x M2 x SE2									
X23 S2 x M x SE						0.07			
X24 S2 x M x SE2									
X25 S2 x M2 x SE									
X26 S2 x M2 x SE2									
X27 Day - 15.5	(D)	4.95			12.33	30.04	29.13	12.33	12.33
X28 Day Quadratic	(D2)	1.10	1.26		2.91			2.91	2.91
X29 S x D		3.29		1.51		0.22	10.34		
X30 S x D2				1.04	1.30	0.29		1.30	1.30

TABLE H-1 DISTRIBUTION OF VARIANCE (%) FOR REGRESSION EQUATION PREDICTORS, SPARES x MANPOWER x SUPPORT EQUIPMENT x DAYS (CONTINUED)

	Categories of Dependent Variables							
	Shop Repair			Spares Supply				
Predictors	47	48	49	55	56	57	58	61
X31 S2 x D				0.84	0.12		0.84	0.84
X32 S2 x D2					0.09			
X33 M x D	0.54				0.23	0.95		
X34 M x D2								
X35 M2 x D							0.35	
X36 M2 x D2				0.49			0.49	0.49
X37 SE x D					10.96			
X38 SE x D2		1.68	1.42		0.07			
X39 SE2 x D				0.35	3.07			0.35
X40 SE2 x D2		1.66	1.78		0.02			
X41 S x M x D				0.32			0.32	0.32
X42 S x M x D2								
X43 S x M2 x D								
X44 S x M2 x D2								
X45 S2 x M x D								
	47	48	49	55	56	57	58	61
X46 S2 x M x D2								
X47 S2 x M2 x D								
X48 S2 x M2 x D2								
X49 S x SE x D					2.55			
X50 S x SE x D2					0.18			
X51 S x SE2 x D				0.69	0.02		0.69	0.69
X52 S x SE2 x D2								
X53 S2 x SE x D					0.05	0.57		
X54 S2 x SE x D2				0.99		0.17	0.99	0.99
X55 S2 x SE2 x D								
X56 S2 x SE2 x D2								
X57 M x SE x D								
X58 M x SE x D2						0.27		
X59 M x SE2 x D								
X60 M x SE2 x D2								

TABLE H-1 DISTRIBUTION OF VARIANCE (%) FOR REGRESSION EQUATION PREDICTORS, SPARES x MANPOWER x SUPPORT EQUIPMENT x DAYS (CONTINUED)

	Categories of Dependent Variables							
	Shop Repair			Spares Supply				
Predictors	47	48	49	55	56	57	58	61
X61 M2 x SE x D					0.11			
X62 M2 x SE x D2						0.31		
X63 M2 x SE2 x D								
X64 M2 x SE2 x D2								
X65 S x M x SE x D								
X66 S x M x SE x D2								
X67 S x M x SE2 x D								
X68 S x M x SE2 x D2								
X69 S x M2 x SE x D						0.51		
X70 S x M2 x SE x D2								
	47	48	49	55	56	57	58	61
X71 S x M2 x SE2 x D								
X72 S x M2 x SE2 x D2					0.03	0.30		
X73 S2 x M x SE x D								
X74 S2 x M x SE x D2								
X75 S2 x M x SE2 x D					0.02	0.13		
X76 S2 x M x SE2 x D2								
X77 S2 x M2 x SE x D								
X78 S2 x M2 x SE x D2								
X79 S2 x M2 x SE2 x D								
X80 S2 x M2 x SE2 x D2								
Number of Predictors in an Equation	10	5	5	13	30	19	13	13
% of Variance Accounted for (R2 x 100)	53.13	12.04	12.35	79.79	98.97	87.36	79.79	79.79
Variance Sub-Totals								
Spares	4.14	0.00	0.00	35.41	11.71	35.81	35.41	35.41
Manpower	1.95	6.42	6.60	0.52	0.78	2.95	0.52	0.52
Support Equipment	36.41	0.00	0.00	23.64	37.70	2.44	23.64	23.64
Day	6.05	1.26	0.00	15.24	30.04	29.13	15.24	15.24
Main Effects	48.55	7.68	6.60	74.81	80.23	70.33	74.81	74.81
2-Factor Interactions	4.58	4.36	5.75	2.98	15.67	13.57	2.98	2.98
3-Factor Interactions				2.00	3.02	2.52	2.00	2.00
4-Factor Interactions					0.05	0.94		
	4.58	4.36	5.75	4.98	18.74	17.03	4.98	4.98

TABLE H-1 DISTRIBUTION OF VARIANCE (%) FOR REGRESSION EQUATION PREDICTORS, SPARES x MANPOWER x SUPPORT EQUIPMENT x DAYS (CONTINUED)

	Categories of Dependent Variables							
	Shop Repair			Spares Supply				
Predictors	47	48	49	55	56	57	58	61
X61 M2 x SE x D					0.11			
X62 M2 x SE x D2						0.31		
X63 M2 x SE2 x D								
X64 M2 x SE2 x D2								
X65 S x M x SE x D								
X66 S x M x SE x D2								
X67 S x M x SE2 x D								
X68 S x M x SE2 x D2								
X69 S x M2 x SE x D						0.51		
X70 S x M2 x SE x D2								
	47	48	49	55	56	57	58	61
X71 S x M2 x SE2 x D								
X72 S x M2 x SE2 x D2					0.03	0.30		
X73 S2 x M x SE x D								
X74 S2 x M x SE x D2								
X75 S2 x M x SE2 x D					0.02	0.13		
X76 S2 x M x SE2 x D2								
X77 S2 x M2 x SE x D								
X78 S2 x M2 x SE x D2								
X79 S2 x M2 x SE2 x D								
X80 S2 x M2 x SE2 x D2								
Number of Predictors in an Equation	10	5	5	13	30	19	13	13
% of Variance Accounted for (R2 x 100)	53.13	12.04	12.35	79.79	98.97	87.36	79.79	79.79
Variance Sub-Totals								
Spares	4.14	0.00	0.00	35.41	11.71	35.81	35.41	35.41
Manpower	1.95	6.42	6.60	0.52	0.78	2.95	0.52	0.52
Support Equipment	36.41	0.00	0.00	23.64	37.70	2.44	23.64	23.64
Day	6.05	1.26	0.00	15.24	30.04	29.13	15.24	15.24
Main Effects	48.55	7.68	6.60	74.81	80.23	70.33	74.81	74.81
2-Factor Interactions	4.58	4.36	5.75	2.98	15.67	13.57	2.98	2.98
3-Factor Interactions				2.00	3.02	2.52	2.00	2.00
4-Factor Interactions					0.05	0.94		
	4.58	4.36	5.75	4.98	18.74	17.03	4.98	4.98

TABLE H-1 DISTRIBUTION OF VARIANCE (%) FOR REGRESSION EQUATION PREDICTORS, SPARES x MANPOWER x SUPPORT EQUIPMENT x DAYS (CONTINUED)

			Categories of Dependent Variables							
			Spares Supply		Support Equipment					
	Predictors		62	63	71	72	73	74	75	79
X1	Spares - 949.50 x .001	(S)	6.64	12.03	0.15	7.40	0.19	0.09	35.32	
X2	Manpower - 1109.667 x .001	(M)	1.91	0.85				0.68	2.05	
X3	Support Equipment	(SE)	25.99	31.31	51.58	4.14	51.27	32.97	3.60	
X4	Spares Quadratic	(S2)	0.44	0.05	0.34		0.32	0.02	1.28	0.65
X5	Manpower Quadratic	(M2)		0.02				0.04		
X6	Support Equipment Quadratic	(SE2)	1.30	8.59	9.12	1.57	9.16	8.36	0.36	39.93
X7	S x M							0.04		
X8	S x M2							0.36		1.01
X9	S2 x M									
X10	S2 x M2									
X11	S x SE				15.89		16.26	0.05	0.30	16.94
X12	S x SE2			0.02		0.83				1.80
X13	S2 x SE			0.21	0.16		0.14	0.02		
X14	S2 x SE2				0.14					
X15	M x SE			0.03	1.01		0.99	0.76		1.94
			62	63	71	72	73	74	75	79
X16	M x SE2							0.14		
X17	M2 x SE		0.82	0.36						0.43
X18	M2 x SE2							0.02		
X19	S x M x SE			0.03				0.03	0.41	
X20	S x M x SE2				0.43		0.43			0.34
X21	S x M2 x SE							0.34	1.47	
X22	S x M2 x SE2			0.01				0.02		
X23	S2 x M x SE			0.07						
X24	S2 x M x SE2									
X25	S2 x M2 x SE									
X26	S2 x M2 x SE2						0.15			
X27	Day - 15.5	(D)		28.66	0.30	3.42	0.34	11.66	30.33	9.58
X28	Day Quadratic	(D2)	6.82	0.01				0.65		
X29	S x D		6.39	0.13		2.49		3.39	7.10	
X30	S x D2		2.61	0.33				3.57		

TABLE H-1 DISTRIBUTION OF VARIANCE (%) FOR REGRESSION EQUATION PREDICTORS, SPARES x MANPOWER x SUPPORT EQUIPMENT x DAYS (CONTINUED)

	Categories of Dependent Variables							
	Spares Supply		Support Equipment					
Predictors	62	63	71	72	73	74	75	79
X31 S2 x D	1.45	0.15						
X32 S2 x D2	0.41	0.13					0.80	
X33 M x D		0.20	0.13		0.12	0.49	0.67	0.25
X34 M x D2						0.05		
X35 M2 x D								
X36 M2 x D2								
X37 SE x D	0.87	10.26	5.18		5.27	16.51		
X38 SE x D2	2.63	0.06				1.04		
X39 SE2 x D	1.83	2.81				4.82		
X40 SE2 x D2	0.63	0.02				0.39		
X41 S x M x D	0.44					0.22		
X42 S x M x D2						0.05		
X43 S x M2 x D								
X44 S x M2 x D2								
X45 S2 x M x D		0.03						
	62	63	71	72	73	74	75	79
X46 S2 x M x D2								
X47 S2 x M2 x D		0.02						
X48 S2 x M2 x D2								
X49 S x SE x D	1.60	2.26	4.84		4.83	4.32		4.03
X50 S x SE x D2		0.19				4.45		
X51 S x SE2 x D		0.02	0.24		0.23	1.02		0.88
X52 S x SE2 x D2						1.02		
X53 S2 x SE x D		0.06					0.71	
X54 S2 x SE x D2								
X55 S2 x SE2 x D								
X56 S2 x SE2 x D2			0.41		0.40			
X57 M x SE x D						0.65		
X58 M x SE x D2			0.27		0.30	0.09	0.19	
X59 M x SE2 x D						0.18		
X60 M x SE2 x D2						0.04		

TABLE H-1 DISTRIBUTION OF VARIANCE (%) FOR REGRESSION EQUATION PREDICTORS, SPARES x MANPOWER x SUPPORT EQUIPMENT x DAYS (CONCLUDED)

	Categories of Dependent Variables							
	Spares Supply		Support Equipment					
Predictors	62	63	71	72	73	74	75	79
X61 M2 x SE x D		0.11						
X62 M2 x SE x D2			0.18		0.19		0.42	
X63 M2 x SE2 x D								
X64 M2 x SE2 x D2								
X65 S x M x SE x D						0.25		
X66 S x M x SE x D2						0.08		
X67 S x M x SE2 x D						0.05		
X68 S x M x SE2 x D2						0.05		
X69 S x M2 x SE x D			0.17		0.16		0.73	
X70 S x M2 x SE x D2								
X71 S x M2 x SE2 x D								
X72 S x M2 x SE2 x D2		0.02	0.29		0.27		0.35	
X73 S2 x M x SE x D								
X74 S2 x M x SE x D2								
X75 S2 x M x SE2 x D								
X76 S2 x M x SE2 x D2								
X77 S2 x M2 x SE x D								
X78 S2 x M2 x SE x D2								
X79 S2 x M2 x SE2 x D			0.11		0.12			
X80 S2 x M2 x SE2 x D2								
Number of Predictors in an Equation	17	32	20	6	20	40	17	12
% of Variance Accounted for (R2 x 100)	62.74	99.05	90.94	19.85	91.12	98.98	86.09	77.78
Variance Sub-Totals								
Spares	7.08	12.08	0.49	7.40	0.51	0.11	36.60	0.65
Manpower	1.91	0.87	0.00	0.00	0.00	0.72	2.05	0.00
Support Equipment	27.28	31.31	60.70	5.71	60.43	41.33	3.96	39.93
Day	6.82	28.67	0.30	3.42	0.34	12.31	30.33	9.58
Main Effects	43.09	81.52	61.49	16.53	61.28	54.47	72.94	50.16
2-Factor Interactions	17.61	14.71	22.51	3.32	22.76	31.65	8.87	22.37
3-Factor Interactions	2.04	2.80	6.37		6.53		3.20	5.25
4-Factor Interactions		0.02	0.57		0.55		1.08	
	19.65	17.53	29.45	3.32	29.84	31.65	13.15	27.62

TABLE H-1 DISTRIBUTION OF VARIANCE (%) FOR REGRESSION EQUATION PREDICTORS, SPARES x MANPOWER x SUPPORT EQUIPMENT x DAYS (CONTINUED)

		Categories of Dependent Variables							
		Spares Supply		Support Equipment					
Predictors		62	63	71	72	73	74	75	79
X1 Spares - 949.50 x .001	(S)	6.64	12.03	0.15	7.40	0.19	0.09	35.32	
X2 Manpower - 1109.667 x .001	(M)	1.91	0.85				0.63	2.05	
X3 Support Equipment	(SE)	25.98	31.31	51.58	4.14	51.27	32.97	3.60	
X4 Spares Quadratic	(S2)	0.44	0.05	0.34		0.32	0.02	1.28	0.65
X5 Manpower Quadratic	(M2)		0.02				0.04		
X6 Support Equipment Quadratic	(SE2)	1.30	8.59	9.12	1.57	9.16	8.36	0.36	39.93
X7 S x M							0.04		
X8 S x M2							0.36		1.01
X9 S2 x M									
X10 S2 x M2									
X11 S x SE				15.89		16.24	0.05	0.30	16.94
X12 S x SE2			0.02		0.83				1.80
X13 S2 x SE			0.21	0.16		0.14	0.02		
X14 S2 x SE2				0.14					
X15 M x SE			0.03	1.01		0.99	0.76		1.94
		62	63	71	72	73	74	75	79
X16 M x SE2							0.14		
X17 M2 x SE		0.82	0.36						0.43
X18 M2 x SE2							0.02		
X19 S x M x SE			0.03				0.03	0.41	
X20 S x M x SE2				0.43		0.43			0.34
X21 S x M2 x SE							0.34	1.47	
X22 S x M2 x SE2			0.01				0.02		
X23 S2 x M x SE			0.07						
X24 S2 x M x SE2									
X25 S2 x M2 x SE									
X26 S2 x M2 x SE2						0.15			
X27 Day - 15.5	(D)		28.66	0.30	3.42	0.34	11.66	30.33	9.58
X28 Day Quadratic	(D2)	6.82	0.01				0.65		
X29 S x D		6.39	0.13		2.49		3.39	7.10	
X30 S x D2		2.61	0.33				3.57		

TABLE H-1 DISTRIBUTION OF VARIANCE (%) FOR REGRESSION EQUATION PREDICTORS, SPARES x MANPOWER x SUPPORT EQUIPMENT x DAYS (CONTINUED)

	Categories of Dependent Variables							
	Spares Supply		Support Equipment					
Predictors	62	63	71	72	73	74	75	79
X31 S2 x D	1.45	0.15						
X32 S2 x D2	0.41	0.13					0.80	
X33 M x D		0.20	0.13		0.12	0.49	0.67	0.25
X34 M x D2						0.05		
X35 M2 x D								
X36 M2 x D2								
X37 SE x D	0.87	10.26	5.18		5.27	16.51		
X38 SE x D2	2.63	0.06				1.04		
X39 SE2 x D	1.83	2.81				4.82		
X40 SE2 x D2	0.63	0.02				0.39		
X41 S x M x D	0.44					0.22		
X42 S x M x D2						0.05		
X43 S x M2 x D								
X44 S x M2 x D2								
X45 S2 x M x D		0.03						
	62	63	71	72	73	74	75	79
X46 S2 x M x D2								
X47 S2 x M2 x D		0.02						
X48 S2 x M2 x D2								
X49 S x SE x D	1.60	2.26	4.84		4.83	4.32		4.03
X50 S x SE x D2		0.19				4.45		
X51 S x SE2 x D		0.02	0.24		0.23	1.02		0.88
X52 S x SE2 x D2						1.02		
X53 S2 x SE x D		0.06					0.71	
X54 S2 x SE x D2								
X55 S2 x SE2 x D								
X56 S2 x SE2 x D2			0.41		0.40			
X57 M x SE x D						0.65		
X58 M x SE x D2			0.27		0.30	0.09	0.19	
X59 M x SE2 x D						0.18		
X60 M x SE2 x D2						0.04		

APPENDIX I

MODELS OF INTERACTION
SPARES X MANPOWER X SUPPORT EQUIPMENT X DAYS

This Appendix provides the estimating models of interaction derived from the multiple regression analysis. The first term of each model represents the intercept followed by the regression coefficients associated with the predictors in the estimating model. The total variance is the percent of variation in the dependent variable that can be accounted for by the model. The standard error of estimate of 5.20, for example, computed for dependent variable 03, tells us that the estimated value can be expected to differ from the observed value within $\pm 5.20\%$ in two out of three cases. Due to space limitations in these tables, S2, M2, SE2, D2 and R2 shall be interpreted as S^2, M^2, SE^2, D^2, and R^2, respectively.

TABLE I-1 MODELS OF INTERACTION, SPARES x MANPOWER x SUPPORT EQUIPMENT x DAYS

Percent Accomplished-Missions

```
Variable 03 =  78.6903 + 23.9768 (S) + 4.8397 (M)
             + 8.9021 (SE) - 33.1616 (S2) - 2.4562 (SE2)
             +33.3759 (S x M2 x SE) - 1.3783 (D)
             + 1.7595 (S x D) + 0.9637 (SE x D)
             - 0.3812 (SE2 x D) - 3.5767 (M2 x SE x D)
             - 0.1574 (M2 x SE x D2) + 1.1998 (M2 x SE2 x D)
             + 2.3339 (S x M2 x SE x D) + 0.7142 (S2 x M2 x SE x D2)
             + 2.0982 (S2 x M2 x SE2 x D)
```

Total Variance (R2 x 100) = 91.72
Standard Error of Estimate = 5.20

Percent Accomplished-Sorties

```
Variable 08 =  55.9805 + 27.7055 (S) + 6.7818 (M)
             +14.2978 (SE) - 38.6294 (S2) - 2.8850 (SE2)
             +11.2481 (S x M) + 19.1699 (S x SE) - 5.0227 (S x SE2)
             + 4.0377 (M x SE) - 16.3688 (M2 x SE) + 8.6186 (S x M x SE)
             +11.4445 (S x M2 x SE) + 11.0326 (S2 x M x S) - 1.5051 (D)
             + 1.4033 (S x D) - 0.5717 (M x D) - 0.0154 (SE2 x D2)
             - 0.3544 (S x M2 x D2) + 0.4086 (S x SE x D) + 1.1922 (S2 x SE x D)
             + 0.0642 (S2 x SE2 x D2) + 1.9431 (S x M2 x SE x D)
```

Total Variance (R2 x 100) = 91.08
Standard Error of Estimate = 6.79

TABLE I-1 MODELS OF INTERACTION, SPARES x MANPOWER x SUPPORT EQUIPMENT x DAYS (CONTINUED)

Percent on Sorties (Including Alert)

Variable 15 = 9.6669 + 5.1911 (S) + 1.3880 (M) + 2.6536 (SE)
- 8.6714 (S2) - 0.6608 (SE2) + 3.4372 (S x M)
+ 3.4750 (S x SE) - 1.0480 (S x SE2) + 5.9297 (S x M2 x SE)
+ 2.3786 (S2 x M x SE) - 0.3273 (D) + 0.2245 (S x D)
+ 0.0408 (S2 x D2) - 0.1452 (M x D) - 0.0839 (S x M2 x D2)
+ 0.0822 (S x SE x D) + 0.5983 (S2 x SE x D) - 0.1888 (S2 x SE2 x D)
+ 0.0030 (M x SE2 x D2) - 0.0194 (M2 x SE x D2) + 0.3970 (S x M2 x SE x D)
+ 0.1364 (S2 x M x SE2 x D)

Total Variance (R2 x 100) = 91.89
Standard Error of Estimate = 1.26

Percent in Unscheduled Maintenance-Aircraft

Variable 16 = 21.2553 + 10.8901 (S) + 5.8182 (SE)
-18.3756 (S2) - 1.5791 (SE2) + 9.2015 (S x SE)
- 2.1540 (S x SE2) + 4.2902 (S x M x SE) - 0.6837 (D)
+ 0.5291 (S x D) + 0.0802 (S2 x D2) - 0.1200 (M x D)
+ 0.0066 (SE x D2) - 0.1170 (S x M2 x D2) + 0.2733 (S x SE x D)
- 0.0039 (S x SE2 x D2) + 0.4909 (S2 x SE x D) + 0.0230 (M x SE x D2)
- 0.0972 (M2 x SE x D2) + 0.0329 (S2 x M x SE x D2)

Total Variance (R2 x 100) = 91.65
Standard Error of Estimate = 2.73

TABLE I-1 MODELS OF INTERACTION, SPARES x MANPOWER x SUPPORT EQUIPMENT x DAYS (CONTINUED)

Percent in Scheduled Maintenance-Aircraft

```
Variable 17 =   7.0949 + 2.9700 (S) - 0.8701 (M) + 1.3737 (SE)
              - 3.9915 (S2) + 3.1955 (M2) - 0.3673 (SE2)
              + 0.7112 (S x SE) + 6.0000 (S x M2 x SE) - 0.1120 (D)
              + 0.1489 (S x D) + 0.0740 (S2 x M2 x D2) + 0.0728 (S x SE x D)
              + 0.1439 (S2 x SE x D) - 0.0170 (S x M2 x SE2 x D2)
```

Total Variance (R2 x 100) = 84.31
Standard Error of Estimate = 0.92

Percent in NORS

```
Variable 18 =  44.3111 - 35.4177 (S) + 9.5404 (M) - 19.6121 (SE)
              +47.9891 (S2) - 25.3739 (M2) + 5.3857 (SE2)
              -35.0722 (S x SE) + 8.2297 (S x SE2) + 2.2845 (D)
              - 1.1545 (S x D) + 0.0647 (S x D2) - 0.2343 (S2 x D2)
              - 1.1336 (S x SE x D) + 0.0159 (S x SE2 x D2)
              - 4.5765 (S2 x SE x D) + 1.3648 (S2 x SE2 x D)
```

Total Variance (R2 x 100) = 95.11
Standard Error of Estimate = 6.67

Percent in Mission Wait Status

```
Variable 19 =   0.3845 + 0.1537 (S) + 0.0211 (M)
              - 0.1030 (S2) + 0.1299 (S x M2 x SE) - 0.0098 (D)
              - 0.0118 (S x D) - 0.0136 (M2 x D) + 0.0043 (SE x D)
              + 0.0002 (SE x D2) - 0.0016 (SE2 x D) + 0.0050 (S2 x M2 x D2)
              + 0.0174 (S x M2 x SE x D)
```

Total Variance (R2 x 100) = 79.53
Standard Error of Estimate = 0.06

TABLE I-1 MODELS OF INTERACTION, SPARES x MANPOWER x SUPPORT EQUIPMENT x DAYS (CONTINUED)

Percent in Service Plus Waiting

```
Variable 20 = - 1.7271 - 3.5180 (S) - 13.6764 (M) + 4.9961 (SE)
              +40.0161 (M2) - 1.4889 (SE2) - 21.8538 (S x M) + 65.0333 (S x M2)
              +15.9528 (S x SE) - 5.4042 (S x SE2) - 11.6037 (M x SE)
              + 3.6703 (M x SE2) - 35.2733 (S x M x SE) + 12.6346 (S x M x SE2)
              - 0.0101 (D) + 1.2775 (M x D) - 0.0616 (M x D2) - 2.7815 (M2 x D)
              + 0.1815 (M2 x D2) - 0.0760 (S x SE x D) - 0.0326 (S x SE2 x D)
              + 0.0284 (S x SE2 x D2) + 0.4939 (S2 x SE x D) - 1.1479 (S x M x SE x D)
              + 0.1613 (S x M x SE x D2) - 0.0630 (S x M x SE2 x D2) + 2.7837
                (S x M2 x SE x D)
              - 1.2096 (S2 x M x SE x D)

Total Variance (R2 x 100) = 85.79
Standard Error of Estimate = 3.53
```

Percent in Operationally Ready

```
Variable 21 =  18.0163 + 9.6104 (S) + 5.2219 (M) + 4.7319 (SE)
              -18.2955 (S2) - 11.8113 (M2) + 7.4681 (S x SE)
              - 2.5820 (S2 x SE2) + 4.8763 (M x SE) - 9.3782 (M2 x SE2)
              +13.6078 (S x M x SE) - 8.1575 (S x M2 x SE) + 26.2236 (S2 x M2 x SE2)
              - 0.7556 (D) + 0.3491 (S x D) + 0.0864 (S2 x D2)
              - 0.4058 (M x D) + 0.3152 (S x SE x D) - 0.0851 (S x M2 x SE2 x D2)
              + 3.8962 (S2 x M2 x SE x D)

Total Variance (R2 x 100) = 90.28
Standard Error of Estimate = 3.26
```

TABLE I-1 MODELS OF INTERACTION, SPARES x MANPOWER x SUPPORT EQUIPMENT x DAYS (CONTINUED)

Average Aircraft Post-Sortie Time (Hours)

Variable 22 = 5.3382 - 3.3467 (M) + 6.9267 (M2) - 1.9771 (S x M)
- 0.8864 (M2 x SE2) - 0.0036 (D2)

Total Variance (R2 x 100) = 22.56
Standard Error of Estimate = 1.75

Average Number of Sorties per Aircraft per Day

Variable 23 = 1.6044 + 0.7940 (S) + 0.2533 (M) + 0.3787 (SE)
- 1.3449 (S2) - 0.0955 (SE2) + 0.3124 (S x M) + 0.5522 (S x SE)
- 0.1470 (S x SE2) + 0.2563 (S x M x SE) + 0.2890 (S x M2 x SE)
- 0.0508 (D) + 0.0399 (S x D) + 0.0062 (S2 x D2)
- 0.0232 (M x D) - 0.0094 (S x M2 x D2) + 0.0114 (S x SE x D)
+ 0.0810 (S2 x SE x D) - 0.0248 (S2 x SE2 x D) - 0.0026 (M2 x SE x D2)
+ 0.0585 (S x M2 x SE x D) + 0.0058 (S2 x M x SE x D2)
+ 0.0188 (S2 x M x SE2 x D)

Total Variance (R2 x 100) = 92.87
Standard Error of Estimate = 0.18

TABLE I-1 MODELS OF INTERACTION, SPARES x MANPOWER x SUPPORT EQUIPMENT x DAYS (CONTINUED)

Flying Hours

Variable 24 = 167.0457 + 89.7089 (S) + 23.9802 (M) + 45.8563 (SE)
-149.8580 (S2) - 11.4209 (SE2) + 59.4269 (S x M) + 60.0496 (S x SE)
- 18.1122 (S x SE2) + 102.4491 (S x M2 x SE) + 41.1134 (S2 x M x SE)
- 5.6553 (D) + 3.8780 (S x D) + 0.7053 (S2 x D2)
- 2.5087 (M x D) - 1.4509 (S x M2 x D2) + 1.4232 (S x SE x D)
+ 10.3301 (S2 x SE x D) - 3.2594 (S2 x SE2 x D) + 0.0513 (M x SE2 x D2)
- 0.3354 (M2 x SE x D2) + 6.8448 (S x M2 x SE x D)
+ 2.3571 (S2 x M x SE2 x D)

Total Variance (R2 x 100) = 91.89
Standard Error of Estimate = 21.85

Average Aircraft Pre-Sortie Time (Hours)

Variable 18 = No predictors met the 0.001 significance level for entry into the model.

Percent Utilization-Manpower

Variable 28 = 19.7026 + 7.5719 (S) 15.3703 (M) + 6.2896 (SE)
-18.4541 (S2) - 1.8785 (SE2) - 4.5042 (S x M) + 49.3531 (S2 x M2)
+ 6.4976 (S x SE) - 1.4232 (S x SE2) - 0.4593 (D)
+ 0.3056 (S x D) + 0.1063 (M x D) + 0.0233 (M x D2)
- 0.8419 (S x M x D) + 1.8273 (S x M2 x D) + 0.2370 (S x SE x D)
+ 0.0340 (S2 x SE x D2) - 0.0584 (M2 x SE x D2)
+ 1.6562 (S2 x M2 x SE x D)

Total Variance (R2 x 100) = 92.23
Standard Error of Estimate = 2.45

TABLE I-1 MODELS OF INTERACTION, SPARES x MANPOWER x SUPPORT EQUIPMENT x DAYS (CONTINUED)

Manhours Used (x100)

$$
\begin{aligned}
\text{Variable 29} = \; & 24.9895 + 9.2074\,(S) + 4.6415\,(M) + 7.9408\,(SE) \\
& - 15.9218\,(S2) - 5.0106\,(M2) - 2.3526\,(SE2) + 9.2136\,(S \times SE) \\
& - 1.6196\,(S \times SE2) + 7.8569\,(S \times M \times SE) - 0.6132\,(D) \\
& + 0.6141\,(S \times D) - 0.3496\,(M \times D) + 0.1933\,(S \times SE \times D) \\
& + 0.4119\,(S2 \times SE \times D) + 0.0494\,(S2 \times SE \times D2) + 0.0267\,(M \times SE \times D2) \\
& - 0.0803\,(M2 \times SE \times D2) + 1.1127\,(S \times M2 \times SE \times D) \\
& - 0.0541\,(S \times M2 \times SE2 \times D2) + 0.3125\,(S2 \times M \times SE2 \times D)
\end{aligned}
$$

Total Variance (R2 x 100) = 91.31
Standard Error of Estimate = 2.87

Percent Unscheduled Maintenance-Manpower

$$
\begin{aligned}
\text{Variable 30} = \; & 67.1279 + 4.1726\,(SE) - 1.6393\,(SE2) - 0.1162\,(D) \\
& + 0.3803\,(S \times D) + 0.0243\,(S \times D2) - 0.7654\,(S2 \times D) \\
& - 0.0521\,(S2 \times D2)
\end{aligned}
$$

Total Variance (R2 x 100) = 45.31
Standard Error of Estimate = 3.25

Percent Scheduled Maintenance-Manpower

$$
\begin{aligned}
\text{Variable 31} = \; & 32.8721 - 4.1726\,(SE) + 1.6393\,(SE2) + 0.1162\,(D) \\
& - 0.3803\,(S \times D) - 0.0243\,(S \times D2) + 0.7654\,(S2 \times D) \\
& + 0.0521\,(S2 \times D2)
\end{aligned}
$$

Total Variance (R2 x 100) = 45.31
Standard Error of Estimate = 3.25

TABLE I-1 MODELS OF INTERACTION, SPARES x MANPOWER x SUPPORT EQUIPMENT x DAYS (CONTINUED)

Number of Personnel Demanded

$$
\begin{aligned}
\text{Variable 33} = {} & 2991.4634 + 1346.9537\,(S) + 410.6932\,(M) \\
& + 610.2644\,(SE) - 2219.5093\,(S2) - 154.9333\,(SE2) \\
& + 450.7396\,(S \times M) + 974.8350\,(S \times SE) - 250.8930\,(S \times SE2) \\
& + 548.7833\,(S \times M \times SE) + 286.1341\,(S \times M2 \times SE) \\
& - 77.7801\,(D) + 70.7767\,(S \times D) + 5.7319\,(S2 \times D2) \\
& - 43.5104\,(M \times D) - 15.4740\,(S \times M2 \times D2) \\
& + 19.2610\,(S \times SE \times D) + 60.7247\,(S2 \times SE \times D) \\
& + 3.8170\,(S2 \times SE \times D2) + 2.2309\,(M \times SE \times D2) \\
& - 8.6585\,(M2 \times SE \times D) + 104.6723\,(S \times M2 \times SE \times D) \\
& + 4.9242\,(S2 \times M \times SE \times D2) + 38.4573\,(S2 \times M \times SE2 \times D)
\end{aligned}
$$

Total Variance (R2 x 100) = 92.37
Standard Error of Estimate = 312.51

Percent Personnel Available (Prime)

$$
\begin{aligned}
\text{Variable 34} = {} & 96.4646 - 0.4490\,(S) + 39.9449\,(M) - 2.2939\,(SE) \\
& + 10.9978\,(S2) - 77.2438\,(M2) + 26.5042\,(S \times M) \\
& - 57.5232\,(S \times M2) - 17.4967\,(S2 \times M) - 2.8571\,(S \times SE) \\
& + 3.4964\,(M2 \times SE) + 0.2331\,(D) + 0.2964\,(S \times D) \\
& - 0.1122\,(S2 \times D2) - 1.1072\,(M \times D) + 1.9967\,(M2 \times D) \\
& + 2.5184\,(S \times M \times D) - 6.3011\,(S \times M2 \times D) + 0.4350\,(S2 \times M2 \times D2) \\
& - 0.1812\,(S \times SE \times D) - 0.2679\,(S2 \times SE \times D) \\
& + 0.0304\,(S \times M2 \times SE2 \times D2)
\end{aligned}
$$

Total Variance (R2 x 100) = 94.23
Standard Error of Estimate = 2.92

TABLE I-1 MODELS OF INTERACTION, SPARES x MANPOWER x SUPPORT EQUIPMENT x DAYS (CONTINUED)

Percent Demands Not Satisfied-Manpower

Variable 38 = 3.1342 + 0.6927 (S) - 39.2844 (M) + 2.1560 (SE) - 11.0965 (S2)
+76.6993 (M2) - 26.0898 (S x M) + 53.3647 (S x M2)
+17.4242 (S2 x M) + 2.1553 (S x SE) - 3.3147 (M2 x SE2)
- 0.2178 (D) - 0.3126 (S x D) + 0.1143 (S2 x D2) + 1.1082 (M x D)
- 2.0183 (M2 x D) - 2.4552 (S x M x D) + 6.2585 (S x M2 x D)
- 0.4258 (S2 x M2 x D2) + 0.1707 (S x SE x D) + 0.2593 (S2 x SE x D)

Total Variance (R2 x 100) = 94.13
Standard Error of Estimate = 2.87

Simulated Maintenance Manhours per Flying Hour

Variable 40 = 15.2363 - 2.8164 (S) + 2.9376 (S2) - 1.5407 (S x M)
+ 0.1721 (D) - 0.1556 (S x D) + 0.0105 (M x D2)
- 0.0242 (M2 x D2) - 0.0281 (SE x D)

Total Variance (R2 x 100) = 47.66
Standard Error of Estimate = 1.92

Number of Reparable Generations

Variable 44 = 60.6850 + 27.4786 (S) + 11.2923 (M) + 14.2271 (SE)
-51.5663 (S2) - 11.9734 (M2) - 3.4319 (SE2)
+12.2334 (S x SE) + 16.6231 (S x M x SE) + 8.1602 (S x M2 x SE)
- 1.8515 (D) + 1.4511 (S x D) + 0.2488 (S2 x D2)
- 0.7971 (M x D) + 0.7147 (S x SE x D) + 1.4029 (S2 x SE x D)
+ 0.0628 (M x SE x D2) - 0.1559 (M2 x SE x D2)
- 0.1538 (S x M2 x SE2 x D2)

Total Variance (R2 x 100) = 86.75
Standard Error of Estimate = 9.44

TABLE I-1 MODELS OF TINTERACTION, SPARES x MANPOWER x SUPPORT EQUIPMENT x DAYS (CONTINUED)

Percent Base Repair

Variable 45 = No predictors met the 0.001 significance level for entry into the model.

Percent Depot Repair

Variable 46 = No predictors met the 0.001 significance level for entry into the model.

Average Base Repair Cycle

Variable 47 = 0.3736 + 0.2531 (S) + 0.4891 (M) + 1.2477 (SE)
- 0.8882 (M2) - 0.6100 (SE2) - 1.2624 (S2 x M)
+ 0.0123 (D) - 0.0008 (D2) + 0.0261 (S x D)
+ 0.0119 (M x D)

Total Variance (R2 x 100) = 53.13
Standard Error of Estimate = 0.33

Percent Active Repair

Variable 48 = 92.2048 + 15.2241 (M) - 4.9893 (M x SE)
- 0.0318 (D2) + 0.1159 (SE x D2) - 0.0463 (SE2 x D2)

Total Variance (R2 x 100) = 12.04
Standard Error of Estimate = 12.93

TABLE I-1 MODELS OF INTERACTION, SPARES x MANPOWER x SUPPORT EQUIPMENT x DAYS (CONTINUED)

Percent White Space

Variable 49 = 8.3202 - 9.2221 (M) + 0.4507 (S x D) + 0.0324 (S x D2)
- 0.0741 (SE x D2) + 0.0323 (SE2 x D2)

Total Variance (R2 x 100) = 12.35
Standard Error of Estimate = 11.47

Percent Fill Rate

Variable 55 = 78.6010 + 17.64[illegible] (S) - 3.3345 (M) + 11.6777 (SE)
- 2.8216 (SE2) - 0.6037 (D) + 0.0219 (D2)
- 0.0431 (S x D2) + 1.0899 (S2 x D) + 0.0974 (M2 x D2)
+ 0.0376 (SE2 x D) - 0.4679 (S x M x D) + 0.0985 (S x SE2 x D)
- 0.0627 (S2 x SE x D2)

Total Variance (R2 x 100) = 79.79
Standard Error of Estimate = 4.24

TABLE I-1 MODELS OF INTERACTION, SPARES x MANPOWER x SUPPORT EQUIPMENT x DAYS (CONTINUED)

Number of Backorder Days-Spares Supply

Variable 56 = 288.5545 - 165.3378 (S) + 90.6632 (M) - 322.5558 (SE)
+ 92.8540 (S2) - 96.7571 (M2) + 103.3233 (SE2)
+ 28.0698 (S x M) + 42.8292 (S2 x SE) - 19.3524 (M x SE)
- 15.6147 (M2 x SE) - 112.7891 (S x M x SE) + 39.7315 (S x M x SE2)
- 61.6816 (S2 x M x SE) + 21.8758 (D) - 3.4851 (S x D)
+ 0.5492 (S x D2) - 12.1188 (S2 x D) - 0.8544 (S2 x D2)
+ 4.3679 (M x D) - 21.5712 (SE x D) + 0.1843 (SE x D2)
+ 6.9290 (SE2 x D) - 0.0644 (SE2 x D2) - 6.2389 (S x SE x D)
- 0.2995 (S x SE x D2) + 1.2725 (S x SE2 x D)
+ 5.4791 (S2 x SE x D) - 5.6461 (M2 x SE x D)
+ 0.3369 (S x M2 x SE2 x D2) - 2.9392 (S2 x M x SE2 x D)

Total Variance (R2 x 100) = 98.97
Standard Error of Estimate = 16.63

Number of Units Demanded-Spares Supply

Variable 57 = 260.3038 + 98.3913 (S) + 41.8846 (M) + 42.4150 (SE)
-187.6251 (S2) - 11.2153 (SE2) + 97.9206 (S x SE)
- 22.8468 (S x SE2) - 23.2536 (M2 x SE) + 75.7326 (S x M x SE)
- 6.9265 (D) + 7.9338 (S x D) - 4.1667 (M x D) + 5.1152 (S2 x SE x D)
+ 0.5755 (S2 x SE x D2) + 0.2885 (M x SE x D2) - 0.6765 (M2 x SE x D2)
+15.2106 (S x M2 x SE x D) - 0.4642 (S x M2 x SE2 x D2)
+ 3.5980 (S2 x M x SE2 x D)

Total Variance (R2 x 100) = 87.36
Standard Error of Estimate = 35.52

TABLE I-1 MODELS OF INTERACTION, SPARES x MANPOWER x SUPPORT EQUIPMENT x DAYS (CONTINUED)

Percent Units Off-the-Shelf

Variable 58 = 78.6010 + 17.6420 (S) - 3.3345 (M) + 11.6777 (SE)
- 2.8217 (SE2) - 0.6037 (D) + 0.0219 (D2)
- 0.0431 (S x D2) + 1.0899 (S2 x D) + 0.0974 (M2 x D2)
+ 0.0376 (SE2 x D) - 0.4679 (S x M x D) + 0.0985 (S x SE2 x D)
- 0.0627 (S2 x SE x D2)

Total Variance (R2 x 100) = 79.79
Standard Error of Estimate = 4.24

Percent Demands Not Satisfied-Spares Supply

Variable 61 = 21.3989 - 17.6420 (S) + 3.3346 (M) - 11.6778 (SE)
+ 2.8217 (SE2) + 0.6037 (D) - 0.0219 (D) + 0.0431 (S x D2)
- 1.0899 (S2 x D) - 0.0974 (M2 x D2) - 0.0376 (SE2 x D)
+ 0.4679 (S x M x D) - 010985 (S x SE2 x D) + 0.0627 (S2 x SE x D2)

Total Variance (R2 x 100) = 79.79
Standard Error of Estimate = 4.24

Number of Cannibalizations

Variable 62 = 28.0240 - 12.8951 (S) + 6.6011 (M) - 17.3750 (SE)
-15.7261 (S2) + 4.7202 (SE2) - 11.6752 (M2 x SE)
- 0.1006 (D2) + 1.3095 (S x D) + 0.0715 (S x D2)
- 1.5187 (S2 x D) + 0.1804 (S2 x D2) + 0.8462 (SE x D)
+ 0.0877 (SE x D2) - 0.3457 (SE2 x D) - 0.0276 (SE2 x D2)
+ 0.6430 (S x M x D) - 0.5112 (S x SE x D)

Total Variance (R2 x 100) = 62.74
Standard Error of Estimate = 6.75

TABLE I-1 MODELS OF INTERACTION, SPARES x MANPOWER x SUPPORT EQUIPMENT x DAYS (CONTINUED)

Number of Items on Backorder-Spares Supply

Variable 63 = 311.6049 - 166.5863 (S) + 97.5504 (M) - 341.7087 (SE)
+ 78.6445 (S2) - 107.1362 (M2) + 109.0266 (SE2)
- 8.8471 (S x SE2) + 45.3265 (S2 x SE) - 20.3405 (M x SE)
- 16.1360 (M2 x SE) - 35.2963 (S x M x SE) + 41.0468 (S x M2 x SE2)
- 66.9864 (S2 x M x SE) + 21.9987 (D) - 0.0685 (D2)
- 2.5262 (S x D) + 0.5258 (S x D2) - 17.8448 (S2 x D)
- 0.7578 (S2 x D2) + 5.4895 (M x D) - 20.8397 (SE x D)
+ 0.2482 (SE x D2) + 6.7723 (SE2 x D) - 0.0857 (SE2 x D2)
- 15.2049 (S2 x M x D) + 33.7720 (S2 x M2 x D)
- 6.9173 (S x SE x D) - 0.2243 (S x SE x D2)
+ 1.4372 (S x SE2 x D) + 5.8131 (S2 x SE x D)
- 8.9986 (M2 x SE x D) + 0.2375 (S x M2 x SE2 x D2)

Total Variance (R2 x 100) = 99.05
Standard Error of Estimate = 16.34

Equipment Percent Used-Unscheduled Maintenance

Variable 71 = 0.0844 + 0.0448 (S) + 0.6285 (SE) - 0.0918 (S2)
- 0.1848 (SE2) + 0.197 (S x SE) - 0.2597 (S2 x SE)
+ 0.0207 (M x SE) + 0.0738 (S x M x SE2) + 0.3805 (S2 x M2 x SE2)
- 0.0025 (D) - 0.0042 (M x D) - 0.0046 (SE x D)
+ 0.0232 (S x SE x D) - 0.0074 (S x SE2 x D)
+ 0.0010 (S2 x SE2 x D2) + 0.0009 (M x SE x D2)
- 0.0032 (M2 x SE x D2) + 0.0307 (S x M2 x SE x D)
- 0.0012 (S x M2 x SE2 x D2) + 0.0242 (S2 x M2 x SE2 x D)

Total Variance (R2 x 100) = 90.94
Standard Error of Estimate = 0.08

TABLE I-1 MODELS OF INTERACTION, SPARES x MANPOWER x SUPPORT EQUIPMENT x DAYS (CONTINUED)

Equipment Percent Used-Scheduled Maintenance

Variable 72 = 0.0075 + 0.0063 (S) + 0.0104 (SE) - 0.0035 (SE2)
+ 0.0019 (S x SE2) - 0.0003 (D) + 0.0006 (S x D)

Total Variance (R2 x 100) = 19.85
Standard Error of Estimate = 0.01

Equipment Percent Unused

Variable 73 = 99.9080 - 0.0489 (S) - 0.6415 (SE) + 0.0975 (S2)
+ 0.1893 (SE2) - 0.2035 (S x SE) + 0.2035 (S x SE) + 0.2598 (S2 x SE)
- 0.0188 (M x SE) - 0.0740 (S x M x SE2) - 0.[illegible]94 (S2 x M2 x SE2)
+ 0.0027 (D) + 0.0043 (M x D) + 0.0046 (SE x D)
- 0.0234 (S x SE x D) + 0.0074 (S x SE2 x D)
- 0.0010 (S2 x SE2 x D2) - 0.0009 (M x SE x D2)
+ 0.0032 (M2 x SE x D2) - 0.0313 (S x M2 x SE x D)
+ 0.0012 (S x M2 x SE2 x D2) - 0.0256 (S2 x M2 x SE2 x D)

Total Variance (R2 x 100) = 91.12
Standard Error of Estimate = 0.08

TABLE I-1 MODELS OF INTERACTION, SPARES x MANPOWER x SUPPORT EQUIPMENT x DAYS (CONTINUED)

Number of Backorder Days-Support Equipment

```
Variable 74 =  491.4360 + 186.6921 (S) + 195.5213 (M) - 597.5232 (SE)
              -140.9075 (S2) - 229.0259 (M2) + 175.7168 (SE2) + 250.6076 (S x M)
              -110.7101 (S x M2) - 91.1947 (S x SE) + 79.1204 (S2 x SE)
              -148.6038 (M x SE) + 25.8626 (M x SE2) + 57.5745 (M2 x SE2)
              -130.2452 (S x M x SE) - 481.4260 (S x M2 x SE)
              +272.4114 (S x M2 x SE2) + 45.0679 (D) + 1.4658 (D2)
              + 60.1835 (S x D) + 3.9597 (S x D2) + 26.4663 (M x D) + 1.2576 (M x D2)
              - 64.7812 (SE x D) - 2.2874 (SE x D2) + 21.1118 (SE2 x D)
              +  0.7777 (SE2 x D2) + 42.9809 (S x M x D) + 1.9830 (S x  M x D2)
              - 80.6429 (S x SE x D) - 5.8846 (S x SE x D2) + 25.3047 (S x SE2 x D)
              +  1.9471 (S x SE2 x D2) - 37.1975 (M x SE x D) - 2.0574 (M x SE x D2)
              + 12.0062 (M x SE2 x D) + 0.7141 (M x SE2 x D2) - 55.3081 (S x M x SE x D)
              -  3.0799 (S x M x SE x D2) + 16.9999 (S x M x SE2 x D)
              +  1.0640 (S x M x SE2 x D2)
```

Total Variance (R2 x 100) = 98.98
Standard Error of Estimate = 40.45

Number of Units Demanded-Support Equipment

```
Variable 75 =  691.9084 + 343.6932 (S) + 101.6761 (M) + 166.3219 (SE)
              -613.9740 (S2) - 38.9264 (SE2) + 138.9468 (S x SE)
              +181.5808 (S x M x SE) + 131.1823 (S x M2 x SE)
              - 22.1831 (D) + 18.6257 (S x D) + 3.3676 (S2 x D2)
              -  8.5443 (M x D) + 17.7265 (S2 x SE x D)
              +  0.7271 (M x SE x D2) - 1.9606 (M2 x SE x D2)
              + 55.5878 (S x M2 x SE x D) - 2.1097 (S x M2 x SE2 x D2)
```

Total Variance (R2 x 100) = 86.09
Standard Error of Estimate = 115.65

TABLE I-1 MODELS OF INTERACTION, SPARES x MANPOWER x SUPPORT EQUIPMENT x DAYS (CONCLUDED)

Equipment Percent Demands Not Satisfied

Variable 79 = 3.9751 - 1.1614 (S2) - 0.4435 (SE2) + 2.3810 (S x M2)
+2.3470 (S x SE) - 0.7742 (S x SE2) + 0.6581 (M x SE)
-1.2194 (M2 x SE) + 0.2822 (S x M x SE2) - 0.0490 (D)
-0.0234 (M x D) + 0.1991 (S x SE x D) - 0.0750 (S x SE2 x D)

Total Variance (R2 x 100) = 77.78
Standard Error of Estimate = 0.65

APPENDIX J

SAMPLE COMPUTATIONS FOR ESTIMATING VALUES WITH REGRESSION MODELS

This Appendix illustrates how an estimated value is computed from an equation.

The estimating model on the left-side of a table is one of many selected from Appendices G or I, except that the intercept and the regression coefficients are listed verticaly instead of horizontally in a series. This format was used to show the match-up of each term on the left with a computed value on the right, after substituting the appropriate value for Spares (S), Manpower (M), Support Equipment (SE), etc.

Observe the first example on table J-1. Observation 1035 of the simulation was associated with 1431 spare units, 1578 maintenance people, 2 avionics intermediate shops, and the 15th day of surge. Therefore, the second term of the equation,

$$
\begin{aligned}
&+23.9768\ (S - 949.50 \times .001)\\
&= +23.9768\ (S - \text{Mean of } S \times .001)\\
&= +23.9768\ (1431 - 949.50 \times .001)\\
&= +23.9768\ (0.4815)
\end{aligned}
$$

which was the computed value for this term. The computed values for the succeeding terms were similarly derived. After multiplication with the appropriate coefficient, the products were summed to yield an estimated value of 99.87.

Table J-1 illustrates sample results for five spares x manpower x support equipment x day equations.

Table J-2 illustrates sample results for five spares x manpower x support equipment equations.

TABLE J-1 SAMPLE COMPUTATIONS OF ESTIMATED VALUES SPARES x MANPOWER x SUPPORT EQUIPMENT x DAY

Variable 03 Percent Accomplished-Missions

	Estimating Model		Estimated Value for Observation 1035	
Intercept	+ 78.6903		+ 78.6903	
X1	+ 23.9768	(S-949.50x.001)	+ 23.9768	(0.4815)
X2	+ 4.8397	(M-1109.667x.001)	+ 4.8397	(0.4683)
X3	+ 8.9021	(SE)	+ 8.9021	(2)
X4	- 33.1616	(S2)	- 33.1616	(0.2318)
X6	- 2.4562	(SE2)	- 2.4562	(4)
X21	+ 33.3759	(S x M2 x SE)	+ 33.3759	(0.2112)
X27	- 1.3783	(D-15.5)	- 1.3783	(-0.5)
X29	+ 1.7595	(S x D)	+ 1.7595	(-0.2407)
X37	+ 0.9637	(SE x D)	+ 0.9637	(-1)
X39	- 0.3812	(SE2 x D)	- 0.3812	(-2)
X61	- 3.5767	(M2 x SE x D)	- 3.5767	(-0.2193)
X62	- 0.1574	(M2 x SE x D2)	- 0.1574	(0.1097)
X63	+ 1.1998	(M2 x SE2 x D)	+ 1.1998	(-0.439)
X69	+ 2.3339	(S x M2 x SE x D)	+ 2.3339	(-0.1056)
X78	+ 0.7142	(S2 x M2 x SE x D2)	+ 0.7142	(0.0254)
X79	+ 2.0982	(S2 x M2 x SE2 x D)	+ 2.0982	(-0.1017)

Sample Results

Observation 1035	96.23
Estimated Value	99.87
Standard Error of Estimate	5.20

Variable 08 Percent Accomplished-Sorties

	Estimating Model		Estimated Value for Observation 1035	
Intercept	+ 55.9805		+ 55.9805	
X1	+ 27.7055	(S-949.50x.001)	+ 27.7055	(0.4815)
X2	+ 6.7818	(M-1109.667x.001)	+ 6.7818	(0.4683)
X3	+ 14.2978	(SE)	+ 14.2978	(2)
X4	- 38.6294	(S2)	- 38.6294	(0.2318)
X6	- 2.8850	(SE2)	- 2.8850	(4)
X7	+ 11.2481	(S x M)	+ 11.2481	(0.2255)
X11	+ 19.1699	(S x SE)	+ 19.1699	(0.963)
X12	- 5.0227	(S x SE2)	- 5.0227	(1.926)
X15	+ 4.0377	(M x SE)	+ 4.0377	(0.9367)
X17	- 16.3688	(M2 x SE)	- 16.3688	(0.4387)
X19	+ 8.6186	(S x M x SE)	+ 8.6186	(0.4510)
X21	+ 11.4445	(S x M2 x SE)	+ 11.4445	(0.2112)
X23	+ 11.0326	(S2 x M x SE)	+ 11.0326	(0.2172)
X27	- 1.5051	(D-15.5)	- 1.5051	(-0.5)
X29	+ 1.4033	(S x D)	+ 1.4033	(-0.2407)
X33	- 0.5717	(M x D)	- 0.5717	(-0.2342)
X40	- 0.0154	(SE2 x D2)	- 0.0154	(1)
X44	- 0.3544	(S x M2 x D2)	- 0.3544	(0.0264)
X49	+ 0.4086	(S x SE x D)	+ 0.4086	(-0.481)
X53	+ 1.1922	(S2 x SE x D)	+ 1.1922	(-0.2318)
X56	+ 0.0642	(S2 x SE2 x D2)	+ 0.0642	(0.232)
X69	+ 1.9431	(S x M2 x SE x D)	+ 1.9431	(-0.1056)

Sample Results

Observation 1035	92.23
Estimated Value	97.08
Standard Error of Estimate	6.79

TABLE J-1 SAMPLE COMPUTATIONS OF ESTIMATED VALUES SPARES x MANPOWER x SUPPORT EQUIPMENT x DAY (CONTINUED)

Variable 18 Percent in NORS

	Estimating Model		Estimated Value for Observation 1035	
Intercept	+ 44.3111		+ 44.3111	
X1	- 35.4177	(S-949.50x.001)	- 35.4177	(0.4815)
X2	+ 9.5404	(M-1109.667x.001)	+ 9.5404	(0.4683)
X3	- 19.6121	(SE)	- 19.6121	(2)
X4	+ 47.9891	(S2)	+ 47.9891	(0.2318)
X5	- 25.3739	(M2)	- 25.3739	(0.2193)
X6	+ 5.3857	(SE2)	+ 5.3857	(4)
X11	- 35.0722	(S x SE)	- 35.0722	(0.963)
X12	+ 8.2297	(S x SE2)	+ 8.2297	(1.926)
X27	+ 2.2845	(D-15.5)	+ 2.2845	(-0.5)
X29	- 1.1545	(S x D)	- 1.1545	(-0.2407)
X30	+ 0.0647	(S x D2)	+ 0.0647	(0.120)
X32	- 0.2343	(S2 x D2)	- 0.2343	(0.0580)
X49	- 1.1336	(S x SE x D)	- 1.1336	(-0.481)
X52	+ 0.0159	(S x SE2 x D2)	+ 0.0159	(0.481)
X53	- 4.5765	(S2 x SE x D)	- 4.5765	(-0.2318)
X55	+ 1.3648	(S2 x SE2 x D)	+ 1.3648	(-0.464)

Sample Results

Observation 1035	0.42
Estimated Value	1.79
Standard Error of Estimate	6.67

Variable 21 Percent in Operationally Ready

	Estimating Model		Estimated Value for Observation 1035	
Intercept	+ 18.0163		+ 18.0163	
X1	+ 9.6104	(S-949.50x.001)	+ 9.6104	(0.4815)
X2	+ 5.2219	(M-1109.667x.001)	+ 5.2219	(0.4683)
X3	+ 4.7319	(SE)	+ 4.7319	(2)
X4	- 18.2955	(S2)	- 18.2955	(0.2318)
X5	- 11.8113	(M2)	- 11.8113	(0.2193)
X11	+ 7.4681	(S x SE)	+ 7.4681	(0.963)
X14	- 2.5820	(S2 x SE2)	- 2.5820	(0.9274)
X15	+ 4.8763	(M x SE)	+ 4.8763	(0.9367)
X18	- 9.3782	(M2 x SE2)	- 9.3782	(0.8773)
X19	+ 13.6078	(S x M x SE)	+ 13.6078	(0.4510)
X21	- 8.1575	(S x M2 x SE)	- 8.1575	(0.2112)
X26	+ 26.2236	(S2 x M2 x SE2)	+ 26.2236	(0.2034)
X27	- 0.7556	(D-15.5)	- 0.7556	(-0.5)
X29	+ 0.3491	(S x D)	+ 0.3491	(-0.2407)
X32	+ 0.0864	(S2 x D2)	+ 0.0864	(0.0580)
X33	- 0.4858	(M x D)	- 0.4858	(-0.2342)
X49	+ 0.3152	(S x SE x D)	+ 0.3152	(-0.481)
X72	- 0.0851	(S x M2 x SE2 x D2)	- 0.0851	(0.1056)
X77	+ 3.8962	(S2 x M2 x SE x D)	+ 3.8962	(-0.0509)

Sample Results

Observation 1035	38.74
Estimated Value	38.66
Standard Error of Estimate	3.26

TABLE J-1 SAMPLE COMPUTATIONS OF ESTIMATED VALUES SPARES x MANPOWER x SUPPORT EQUIPMENT x DAY (CONCLUDED)

Variable 23 Average Number of Sorties per Aircraft per Day

	Estimating Model	Estimated Value for Observation 1035
Intercept	+ 1.6044	+ 1.6044
X1	+ 0.7940 (S-949.50x.001)	+ 0.7940 (0.4815)
X2	+ 0.2533 (M-1109.667x.001)	+ 0.2533 (0.4683)
X3	+ 0.3787 (SE)	+ 0.3787 (2)
X4	- 1.3449 (S2)	- 1.3449 (0.2318)
X6	- 0.0955 (SE2)	- 0.0955 (4)
X7	+ 0.3124 (S x M)	+ 0.3124 (0.2255)
X11	+ 0.5522 (S x SE)	+ 0.5522 (0.963)
X12	- 0.1470 (S x SE2)	- 0.1470 (1.926)
X19	+ 0.2563 (S x M x SE)	+ 0.2563 (0.4510)
X21	+ 0.2890 (S x M2 x SE)	+ 0.2890 (0.2112)
X27	- 0.0508 (Day-15.5)	- 0.0508 (-0.5)
X29	+ 0.0399 (S x D)	+ 0.0399 (-0.2407)
X32	+ 0.0062 (S2 x D2)	+ 0.0062 (0.0580)
X33	- 0.0232 (M x D)	- 0.0232 (-0.2342)
X44	- 0.0094 (S x M2 x D2)	- 0.0094 (0.0264)
X49	+ 0.0114 (S x SE x D)	+ 0.0114 (-0.481)
X53	+ 0.0810 (S2 x SE x D)	+ 0.0810 (-0.2318)
X55	- 0.0248 (S2 x SE2 x D)	- 0.0248 (-0.464)
X62	- 0.0026 (M2 x SE x D2)	- 0.0026 (0.1097)
X69	+ 0.0585 (S x M2 x SE x D)	+ 0.0585 (-0.1056)
X74	+ 0.0058 (S2 x M x SE x D2)	+ 0.0058 (+0.0543)
X75	+ 0.0188 (S2 x M x SE2 x D)	+ 0.0188 (-0.2172)

Sample Results

Observation 1035	2.64
Estimated Value	2.66
Standard Error of Estimate	0.18

TABLE J-2 SAMPLE COMPUTATIONS OF ESTIMATED VALUES SPARES x MANPOWER x SUPPORT EQUIPMENT

Variable 03 Percent Accomplished-Missions

Estimating Model			Estimated Value for Observation 1035	
Intercept	+ 78.5940		+ 78.5940	
X1	+ 24.1222	(S-949.50x.001)	+ 24.1222	(0.4815)
X2	+ 4.1231	(M-1109.667x.001)	+ 4.1231	(0.4683)
X3	+ 3.5384	(SE)	+ 3.5384	(2)
X4	- 26.9612	(S2)	- 26.9612	(0.2318)
X21	+ 32.1211	(S x M2 x SE)	+ 32.1211	(0.2112)

Sample Results

Observation 1035	96.23
Estimated Value	99.75
Standard Error of Estimate	13.53

Variable 08 Percent Accomplished-Sorties

Estimating Model			Estimated Value for Observation 1035	
Intercept	+ 55.9077		+ 55.9077	
X1	+ 29.4092	(S-949.50x.001)	+ 29.4092	(0.4815)
X2	+ 9.4359	(M-1109.667x.001)	+ 9.4359	(0.4683)
X3	+ 5.7461	(SE)	+ 5.7461	(2)
X4	- 30.6195	(S2)	- 30.6195	(0.2318)
X21	+ 63.3809	(S x M2 x SE)	+ 63.3809	(0.2112)

Sample Results

Observation 1035	92.23
Estimated Value	92.27
Standard Error of Estimate	15.71

Variable 18 Percent in NORS

Estimating Model			Estimated Value for Observation 1035	
Intercept	+ 41.3708		+ 41.3708	
X1	- 33.7117	(S-949.50x.001)	- 33.7117	(0.4815)
X3	- 19.6121	(SE)	- 19.6121	(2)
X4	+ 30.4348	(S2)	+ 30.4348	(0.2318)
X6	+ 5.3857	(SE2)	+ 5.3857	(4)
X11	- 16.2327	(S x SE)	- 16.2327	(0.963)

Sample Results

Observation 1035	0.42
Estimated Value	- 1.12
Standard Error of Estimate	20.62

TABLE J-2 SAMPLE COMPUTATIONS OF ESTIMATED VALUES SPARES x MANPOWER x SUPPORT EQUIPMENT (CONCLUDED)

Variable 21 Percent in Operationally Ready

Estimating Model			Estimated Value for Observation 1035	
Intercept	+ 16.5194		+ 16.5194	
X1	+ 9.8780	(S-949.50x.001)	+ 9.8780	(0.4815)
X3	+ 4.8273	(SE)	+ 4.8273	(2)
X4	- 11.0604	(S2)	- 11.0604	(0.2318)
X11	+ 7.4272	(S x SE)	+ 7.4272	(0.963)
X15	+ 7.9308	(M x SE)	+ 7.9308	(0.9367)
X18	- 9.2080	(M2 x SE2)	- 9.2080	(0.8773)
X19	+ 13.6078	(S x M x SE)	+ 13.6078	(0.4510)
X21	- 20.7373	(S x M2 x SE)	- 20.7373	(0.2112)

Sample Results

Observation 1035	38.74
Estimated Value	36.63
Standard Error of Estimate	7.51

Variable 23 Average Number of Sorties Per Aircraft Per Day

Estimating Model			Estimated Value for Observation 1035	
Intercept	+ 1.6363		+ 1.6363	
X1	+ 0.8433	(S-949.50x.001)	+ 0.8433	(0.4815)
X2	+ 0.2818	(M-1109.667x.001)	+ 0.2818	(0.4683)
X3	+ 0.1651	(SE)	+ 0.1651	(2)
X4	- 0.8795	(S2)	- 0.8795	(0.2318)
X21	+ 1.8089	(S x M2 x SE)	+ 1.8089	(0.2112)

Sample Results

Observation 1035	2.64
Estimated Value	2.68
Standard Error of Estimate	0.49